

Advanced Surveying

Chapter- 3

FIELD ASTRONOMY

Prof. Ujval J. Solanki, Darshan Institute of
Engineering and Technology-RAJKOT

Scope of Study

1. Introduction
2. Purposes
3. Astronomical terms
4. Latitude and Longitude
5. Spherical Trigonometry
6. Celestial coordinate system
7. Examples on PZS Triangle
8. Determination of Azimuths

Introduction

- Science deals heavenly bodies such as Sun, Moon planets, Polaris i.e. North Star.
- Find absolute position of any point.
- Angular direction of the Sun, Star relative to Horizon.
- Celestial sphere.
- Motion of Celestial sphere.
- Earth and its Motion

Purposes of Field Astronomy

- Determine absolute location/ position and direction of any line on the surface of the Earth.
- Determine absolute location of any points / object → astronomical observation to celestial bodies such as Moon, Sun, Star and planets.
- Used to find Angular position of Stars.
- Determination of the position of Points on the Earth
- Determination of Orientation.

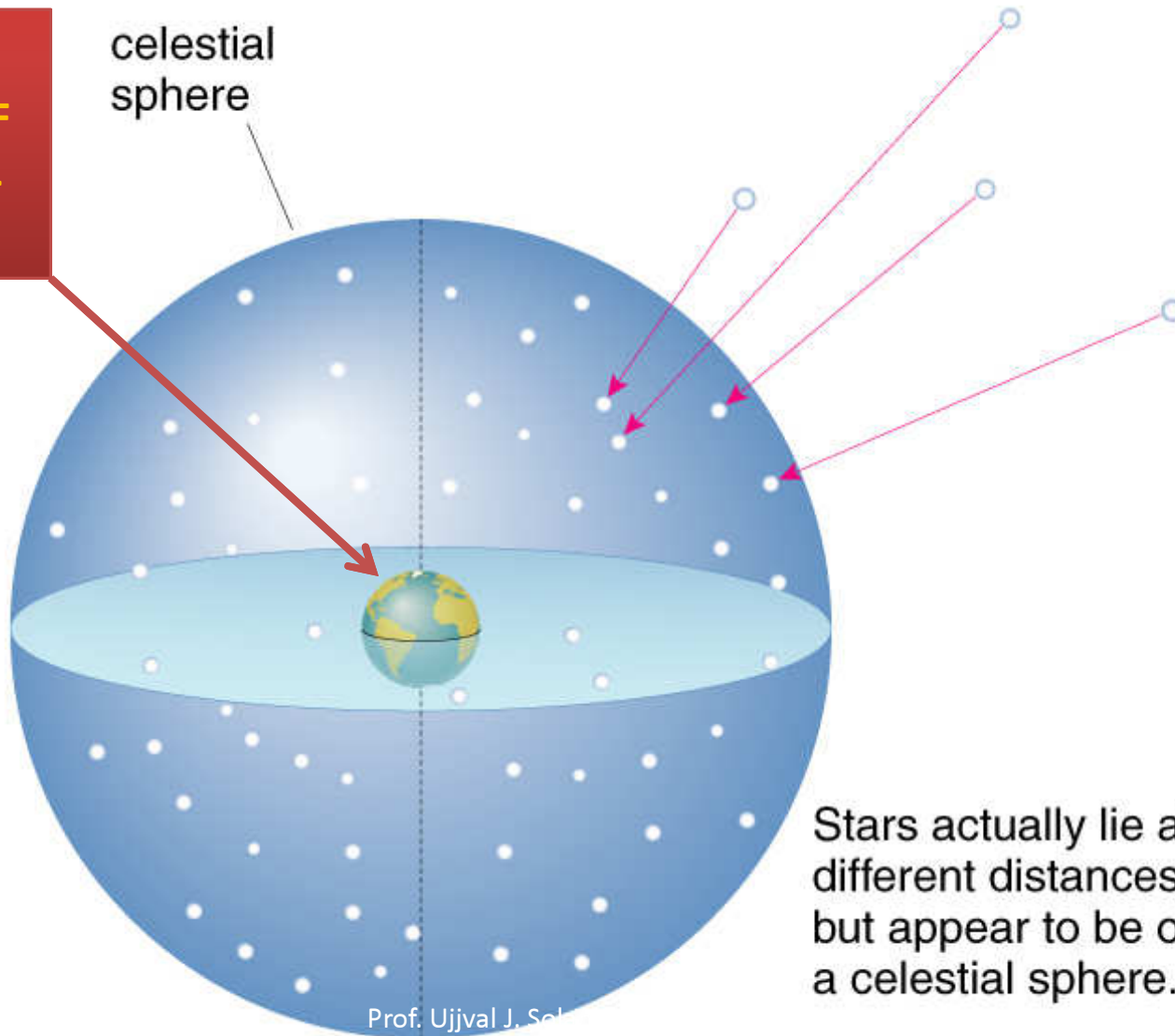
DEFINITION OF ASTRONOMICAL TERMS

(1) The celestial sphere

- The Imaginary sphere on which the stars appear to lie or to be studded is known as the *Celestial sphere*.
- Radius of celestial sphere may be of any value.
- The center of the Earth may be taken as the center of celestial sphere.

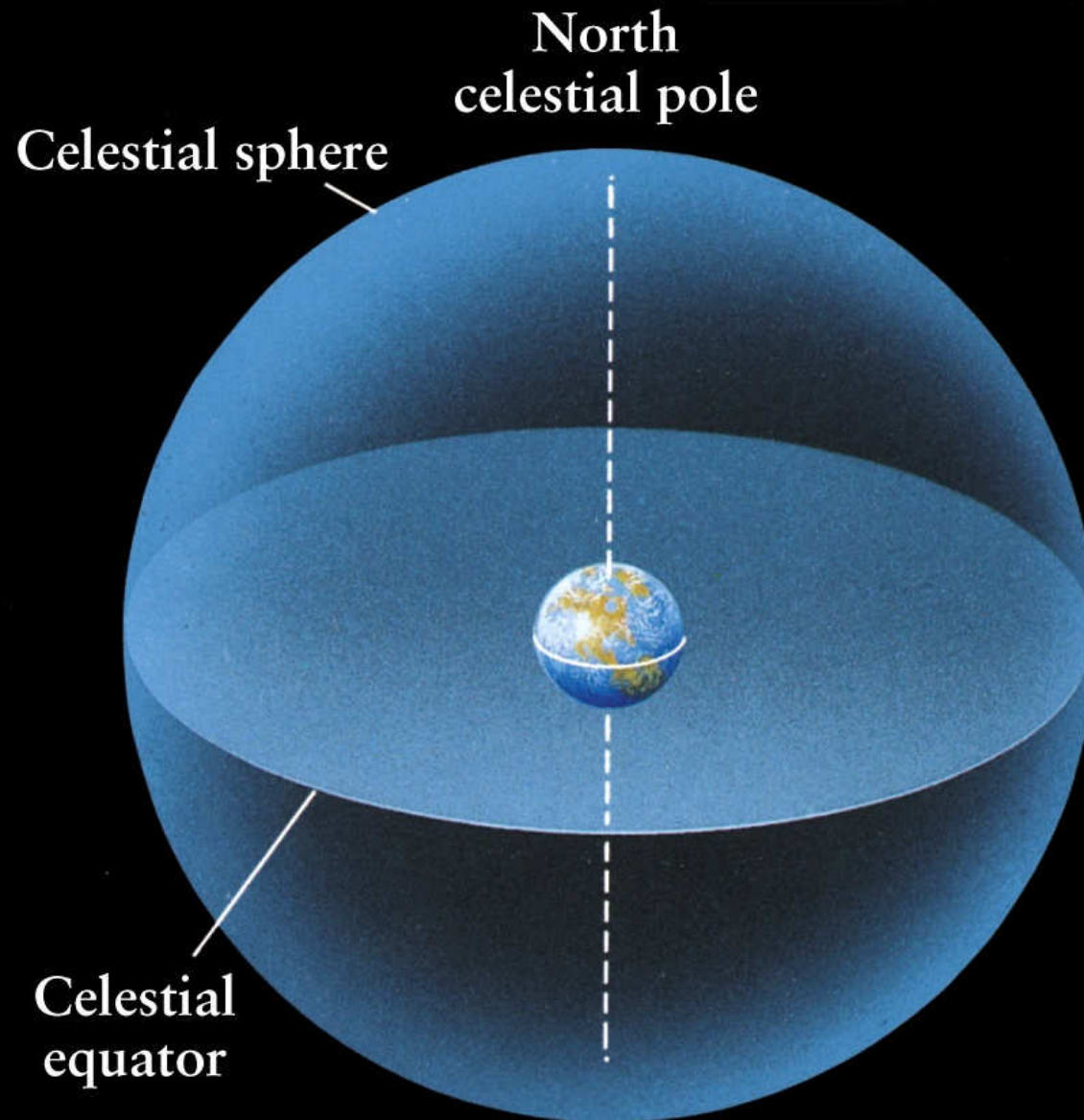
Celestial sphere

**EARTH –
CENTER OF
CELESTIAL
SPHERE**



Stars actually lie at different distances but appear to be on a celestial sphere.

Prof. Ujjval J. Sel



North
celestial pole

South
celestial pole

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DEFINITION OF ASTRONOMICAL TERMS

(2) The Zenith and Nadir :

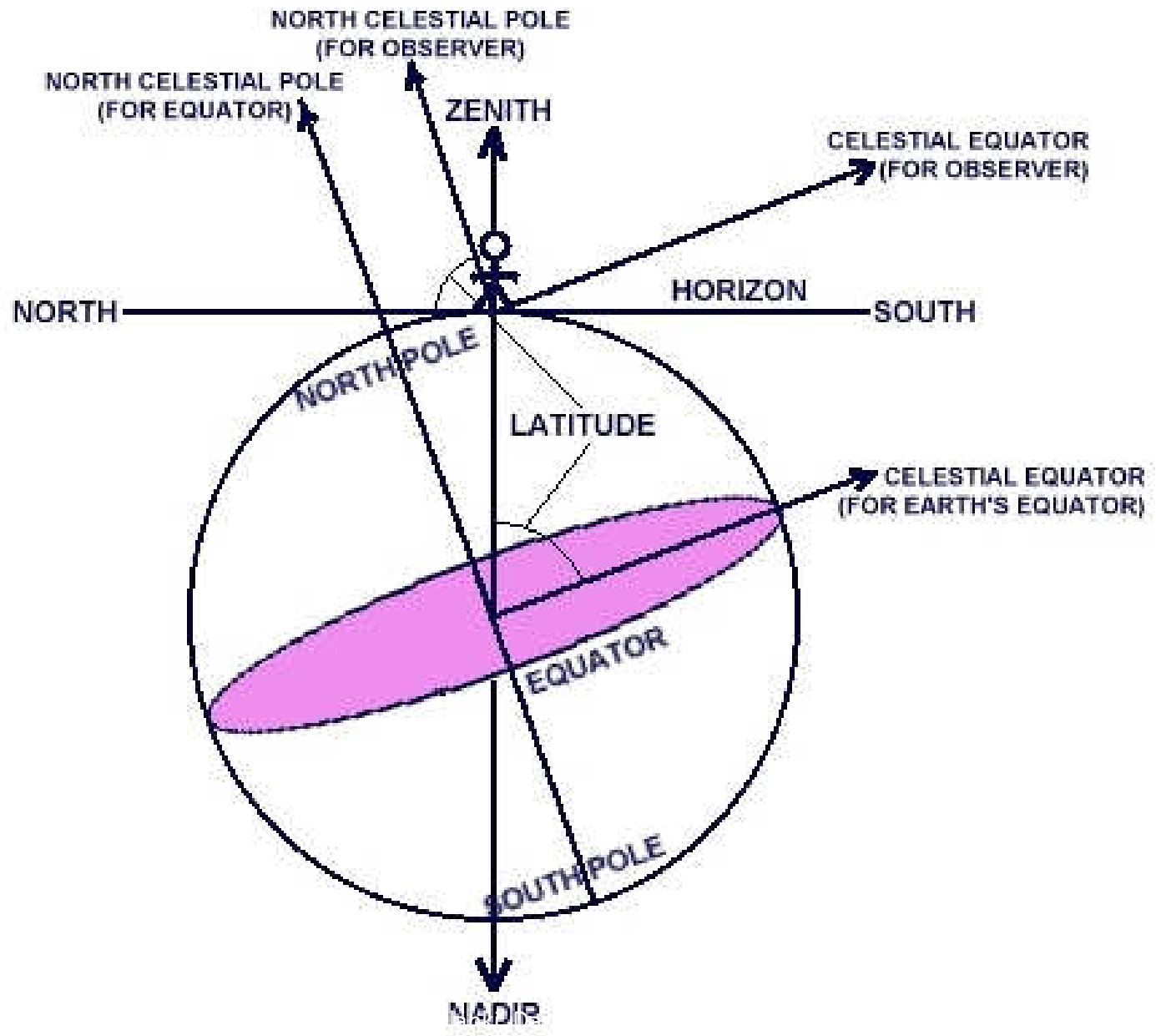
- The Zenith (Z) is the point on the upper portion of the celestial sphere marked by plumb line, above the observer.
- The point on the celestial sphere immediately above the observer's station.

DEFINITION OF ASTRONOMICAL TERMS

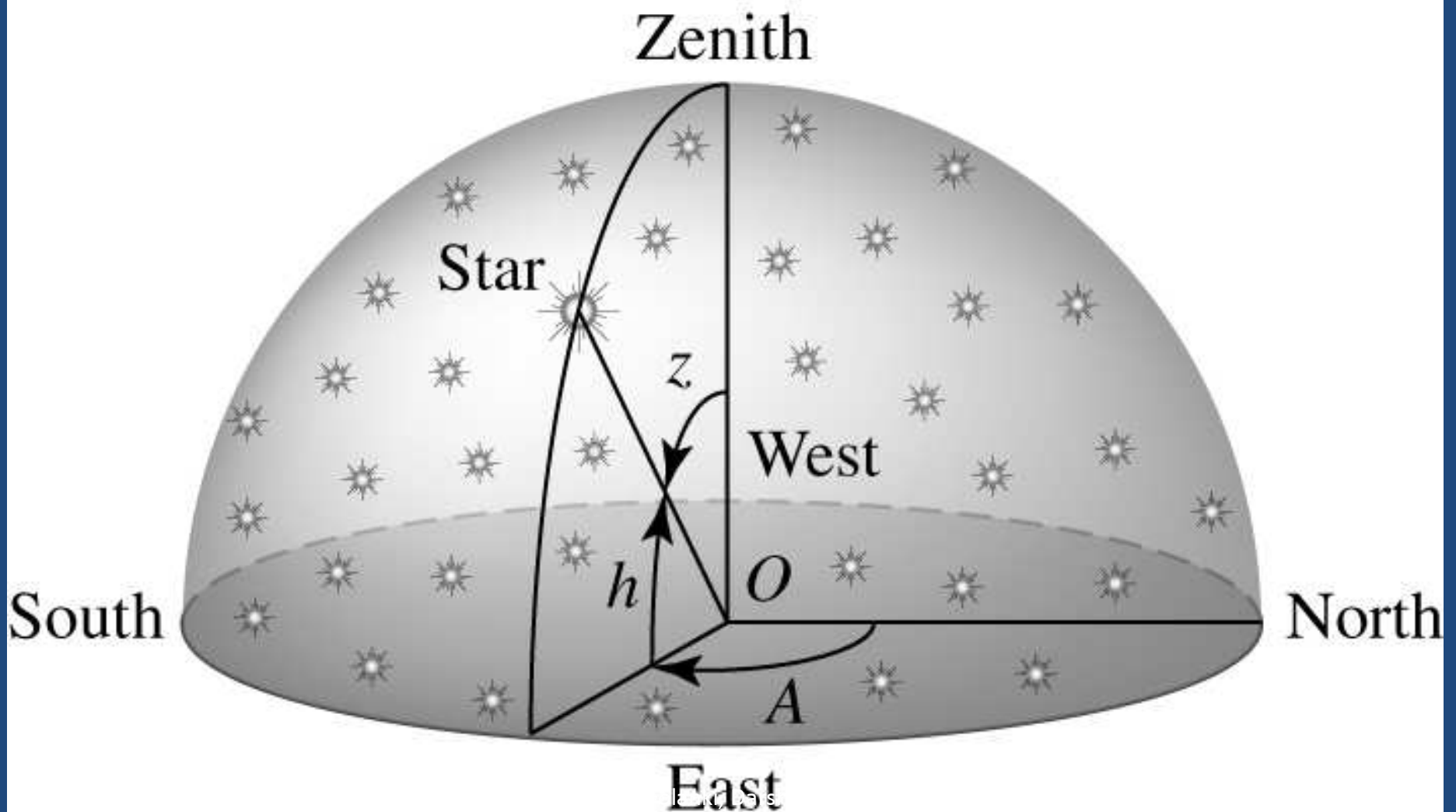
(2)The Zenith and Nadir :

The Nadir (Z'):

- Is the point on the lower portion of the celestial sphere marked by plumb line, below the observer.
- **The point on the celestial sphere vertically below the observer's station.**



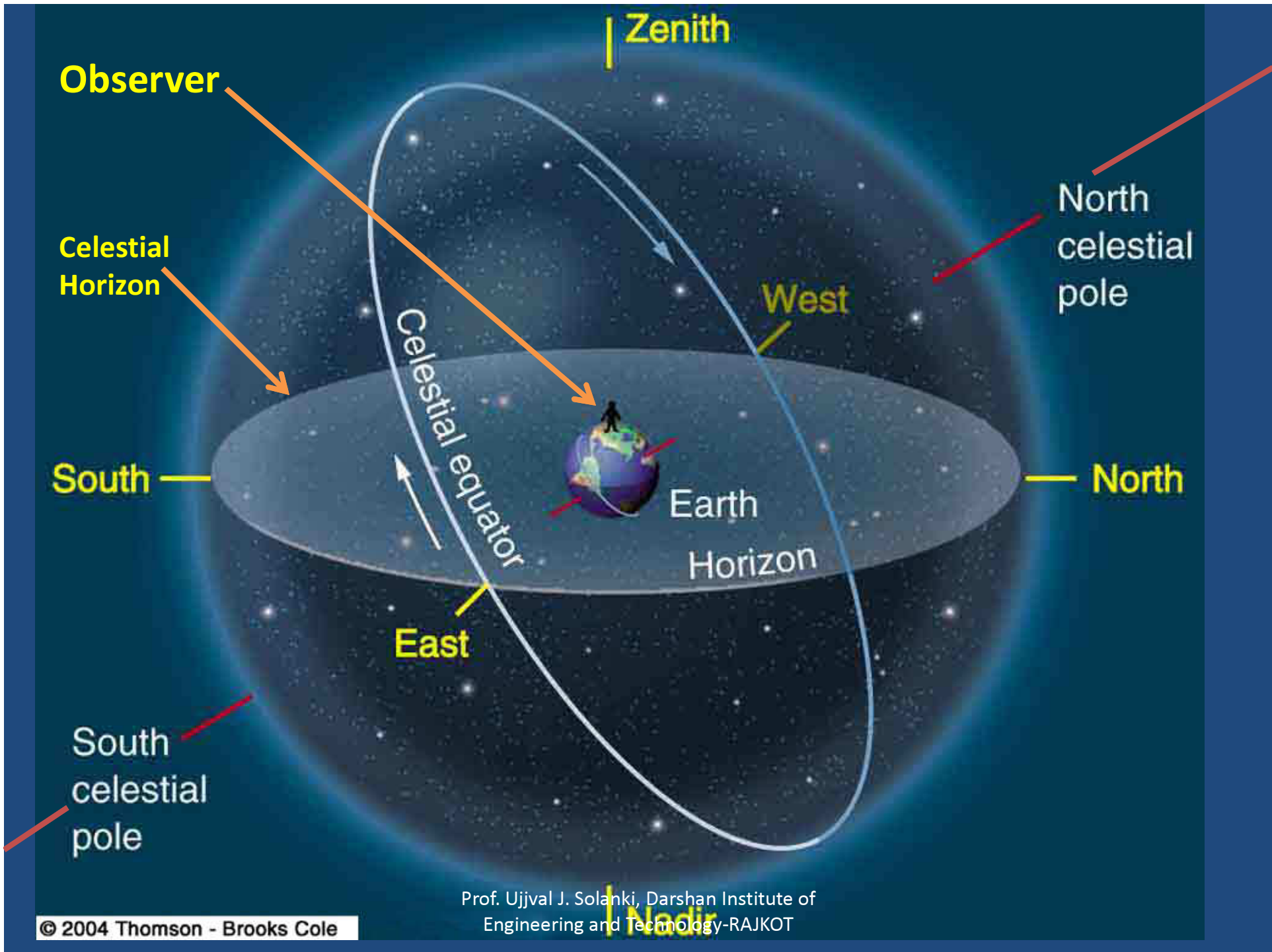
Zenith and Nadir



DEFINITION OF ASTRONOMICAL TERMS

(3) The celestial Horizon / True Horizon/ Geocentric Horizon.

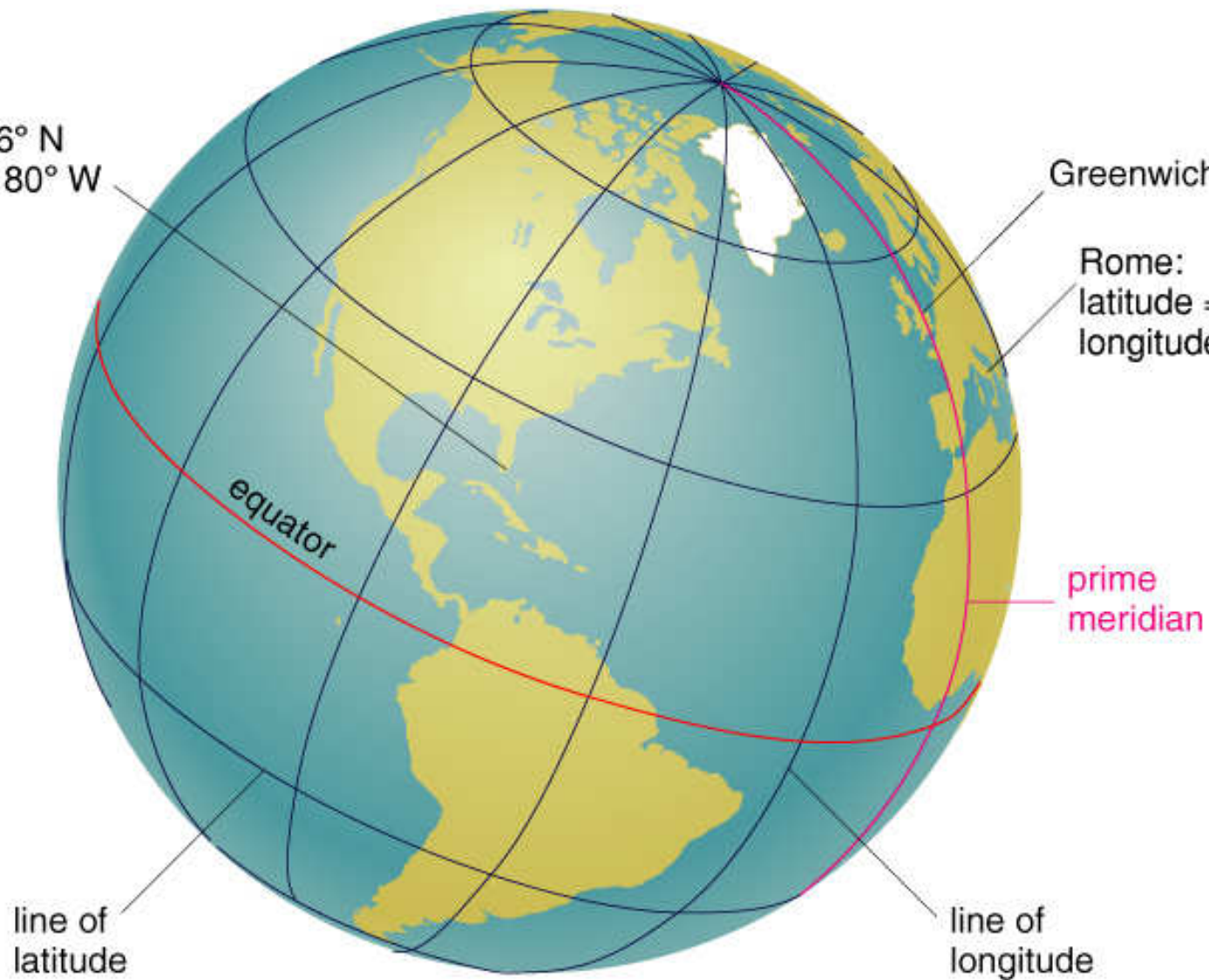
- It is the great circle traced upon the celestial sphere by **the plane which is perpendicular to the Zenith-Nadir line and which passes through the center of the earth.**
- Great circle is a section of a sphere when the cutting plane passes through the centre of the sphere.



Miami:
latitude = 26° N
longitude = 80° W

Greenwich

Rome:
latitude = 42° N
longitude = 12° E



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DEFINITION OF ASTRONOMICAL TERMS

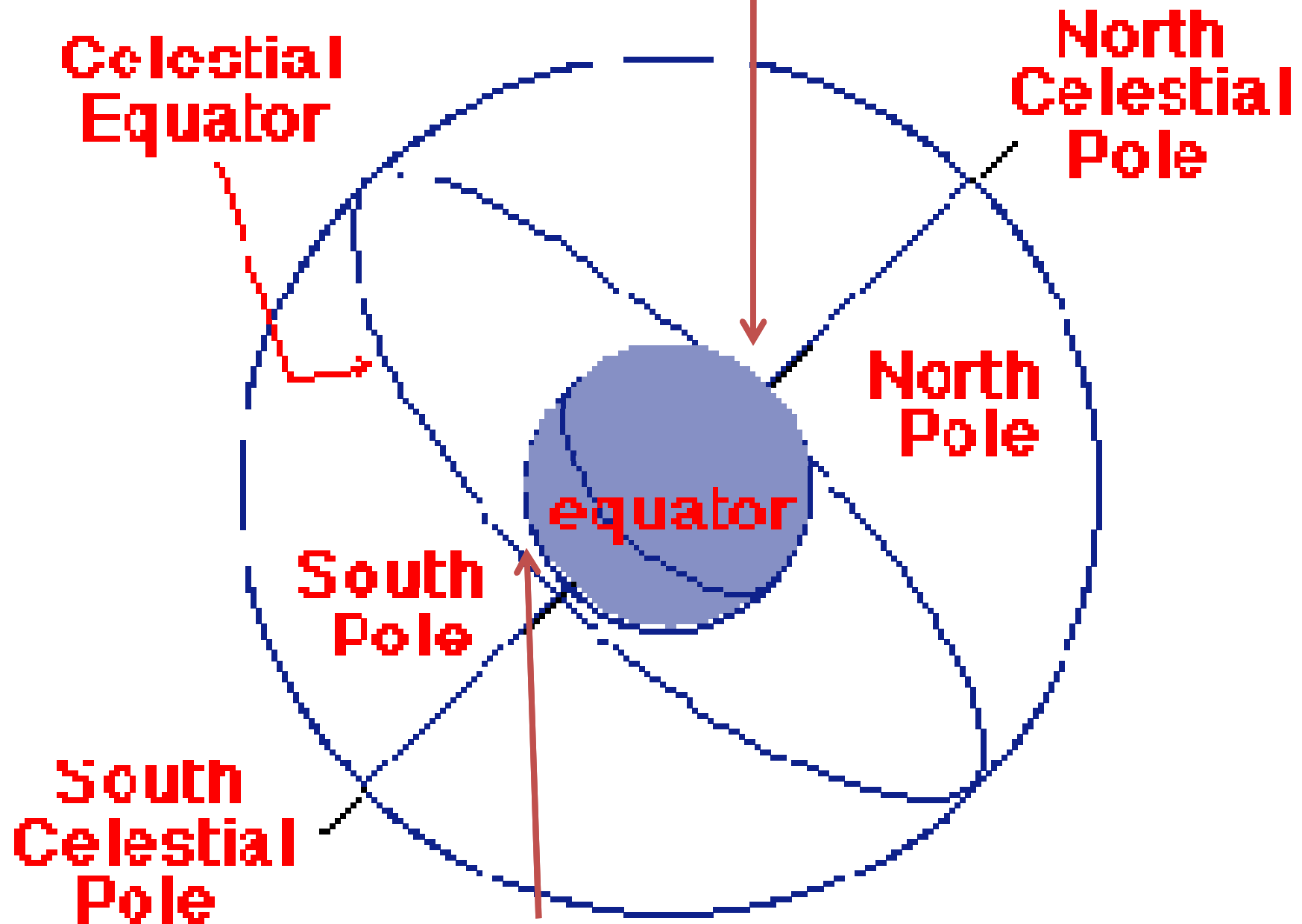
(4)The Terrestrial Poles and Equator:

- The Terrestrial Poles:
- The Terrestrial Poles are the two points in which the Earth's axis of rotation meets the earth's sphere.
- Terrestrial poles are the points where the Earth's surface and Earth axis of rotation meets.

DEFINITION OF ASTRONOMICAL TERMS

- **The Terrestrial Poles and Equator:**
- **The Terrestrial Equator:**
- The Terrestrial Equator is the great circle of the Earth, the plane of which is at right angles to the axis of rotation.
- The two poles are equidistant from it.

North Terrestrial Poles



DEFINITION OF ASTRONOMICAL TERMS

(5) The Celestial Poles and Equator:

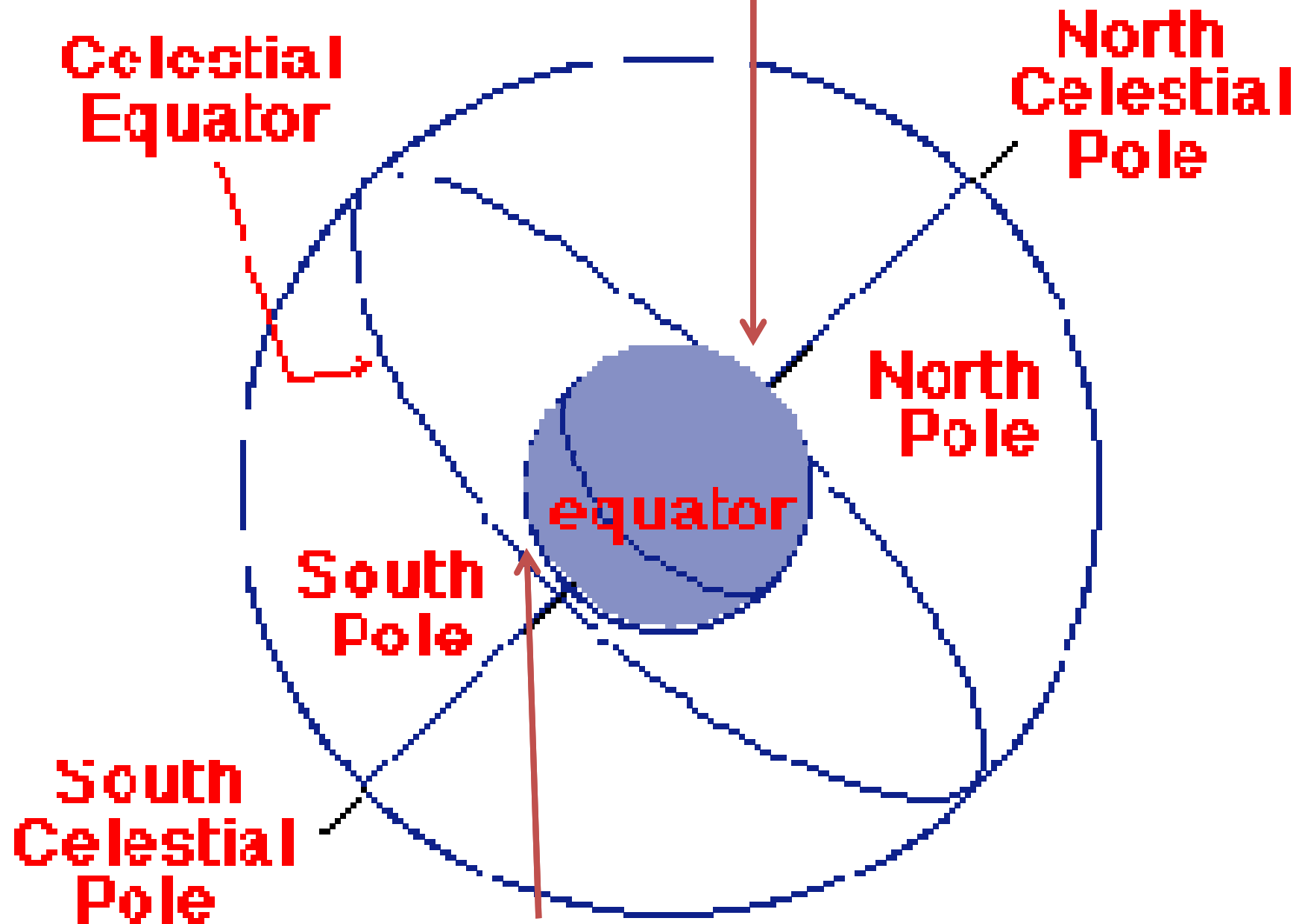
- **The Celestial Poles:**

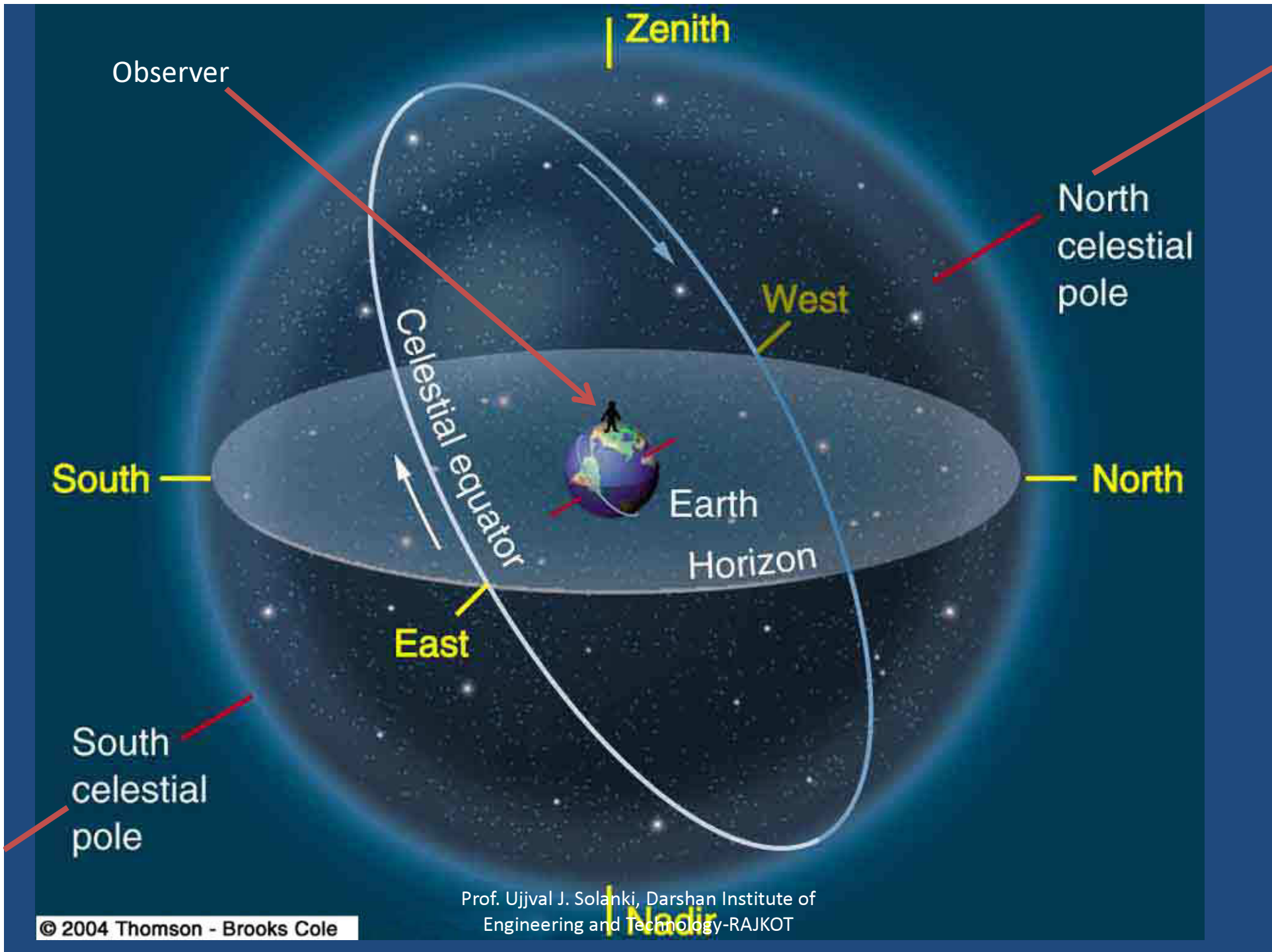
- If the Earth's axis of rotation is produced indefinitely , it will meet the celestial sphere in two points called the North and South celestial poles

- **The Celestial Equator:**

- It is the Great circle of the celestial sphere in which it is intersected by the plane of celestial equator.

North Terrestrial Poles





DEFINITION OF ASTRONOMICAL TERMS

(6) **The Sensible Horizon:**

- The circle in which a plane passing through the Earth's surface and point of observations and tangential to the earth's surface or (normal to the Zenith-nadir line) intersects with celestial sphere is called as the sensible Horizon.
- The line of sight of an accurately levelled telescope lies in this plane.

DEFINITION OF ASTRONOMICAL TERMS

(7)The Visible Horizon:

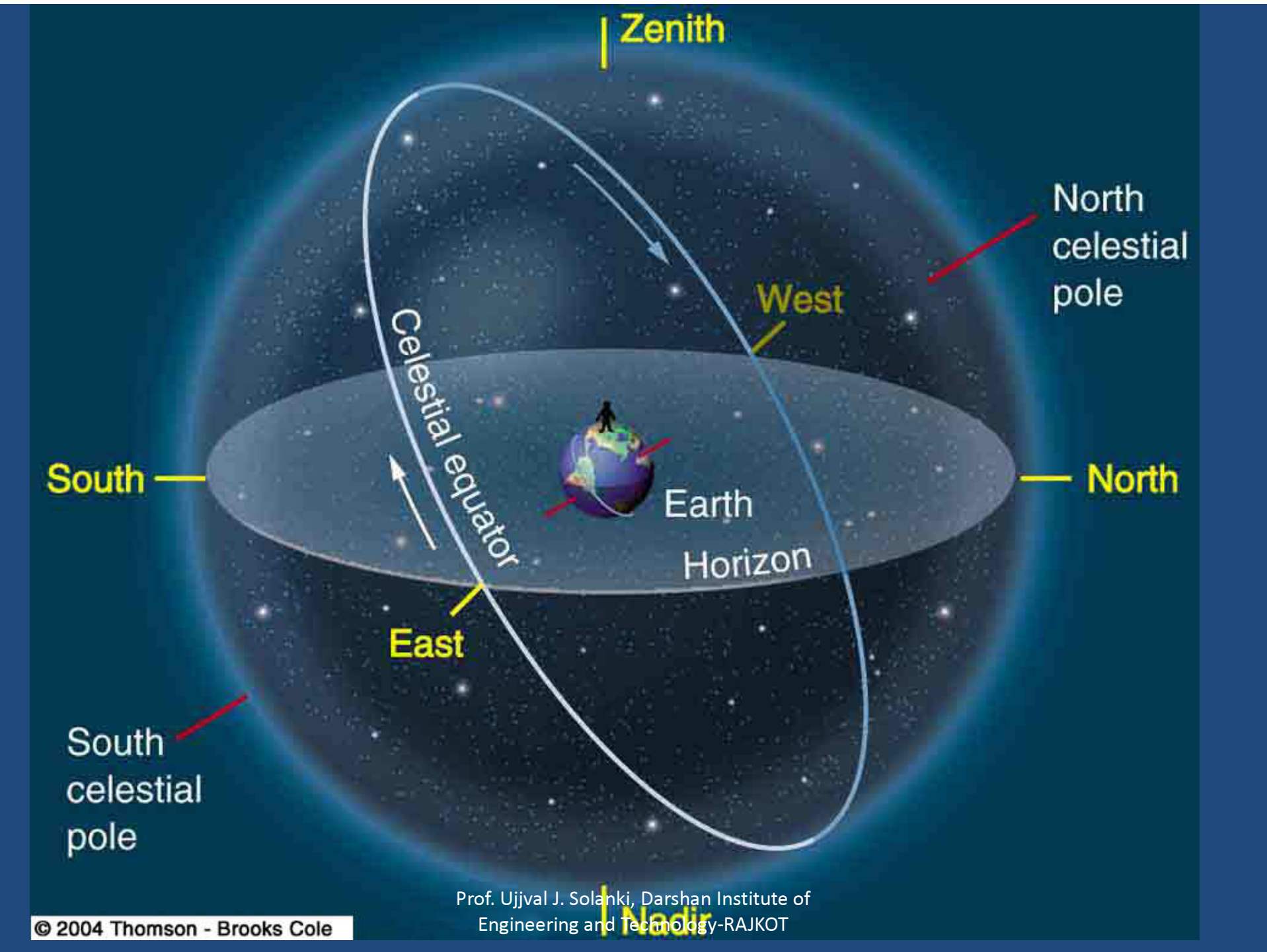
The circle of contact with the Earth surface of the visible rays passing through the point of observation is called as visible horizon.

Visible Horizon is a small circle of Earth.

DEFINITION OF ASTRONOMICAL TERMS

(8)The Vertical Circle.

- A vertical circle of the celestial sphere is a Great circle passing through the Zenith (Z) and Nadir (Z').
- All the vertical circle cut the celestial Horizon at Right Angles.



DEFINITION OF ASTRONOMICAL TERMS

(9) The Observer's Meridian.

- The Meridian of any Particular point is that circle which passes through the Zenith (Z) and Nadir (Z') and Poles P and P₁ of the point as well as through the poles.
- It is thus a vertical circle.

DEFINITION OF ASTRONOMICAL TERMS

(10) The Prime Vertical/ Prime Control

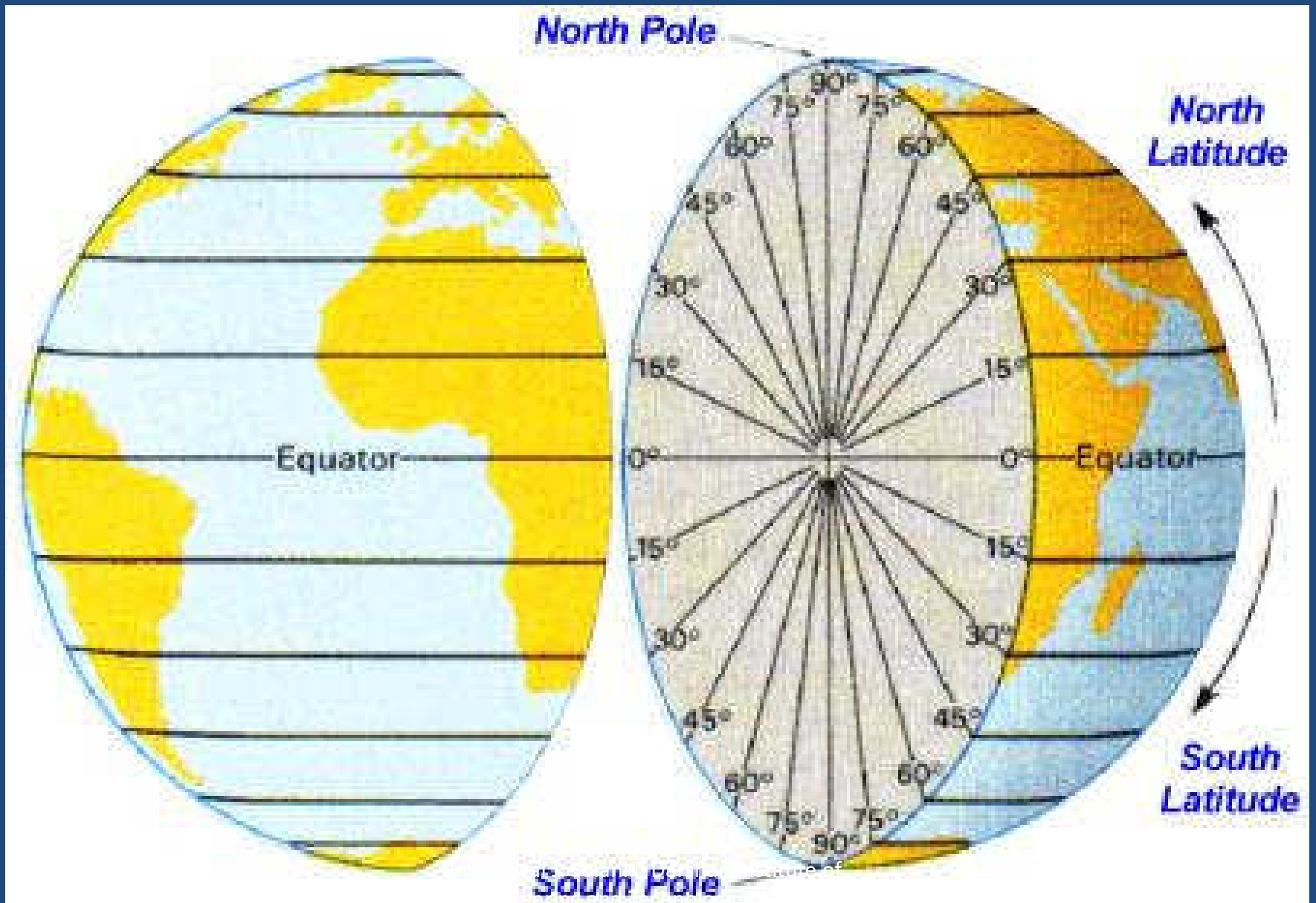
- It is Vertical Circle at 90° to observer's meridian on celestial sphere and passes through the **East and West** points of the horizon is called as prime vertical.

DEFINITION OF ASTRONOMICAL TERMS

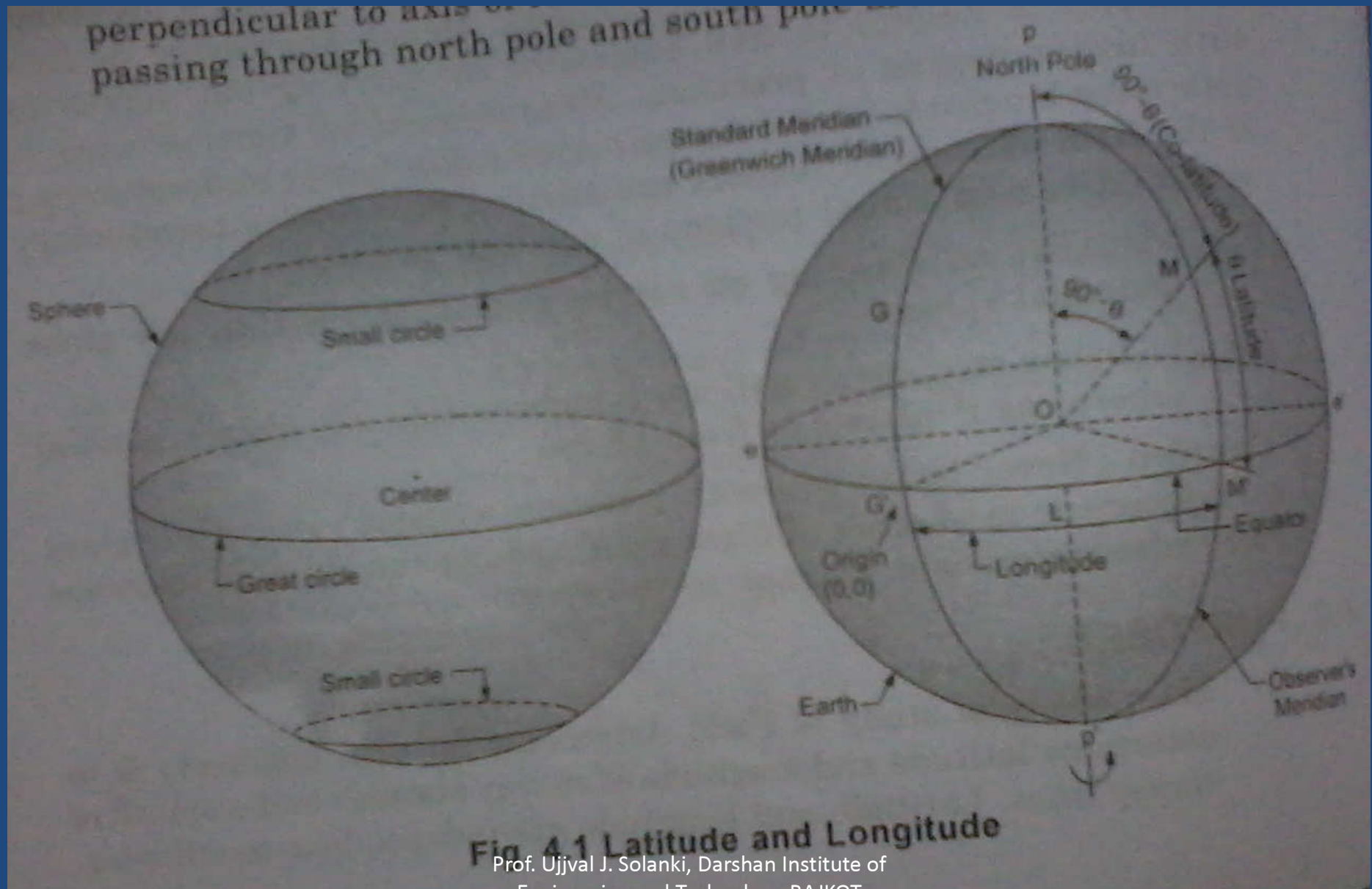
(11) The Latitude (θ)- (Axaans)

- The angle between the direction of a plumb line at the place and the plane of the ~~celestial~~ Equator is called as latitude. It is denoted by ' θ '
- It can also be defined as the angle between the celestial equator and Zenith.

Latitude

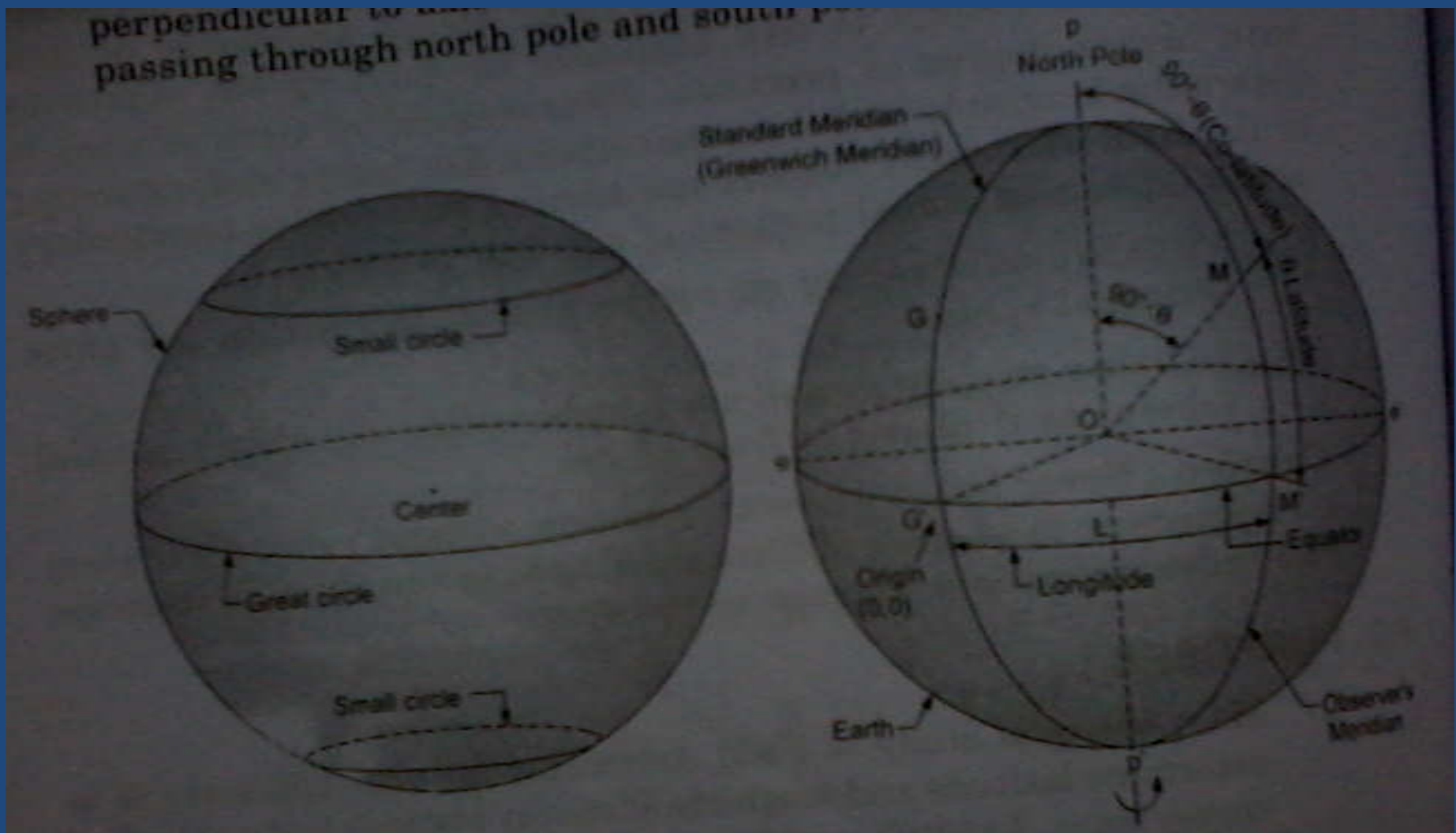


Longitude of M -0 to 180 E or W



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Latitude of M



Latitude = Angle $\text{MOM}' = \text{Arc } \text{M}'\text{M}$

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DEFINITION OF ASTRONOMICAL TERMS

(12) The Co-Latitude (c):

- The co-latitude of a place is the angular distance from the Zenith to the pole .
- It is compliment of the latitude and equal to $(90 - \theta)$.

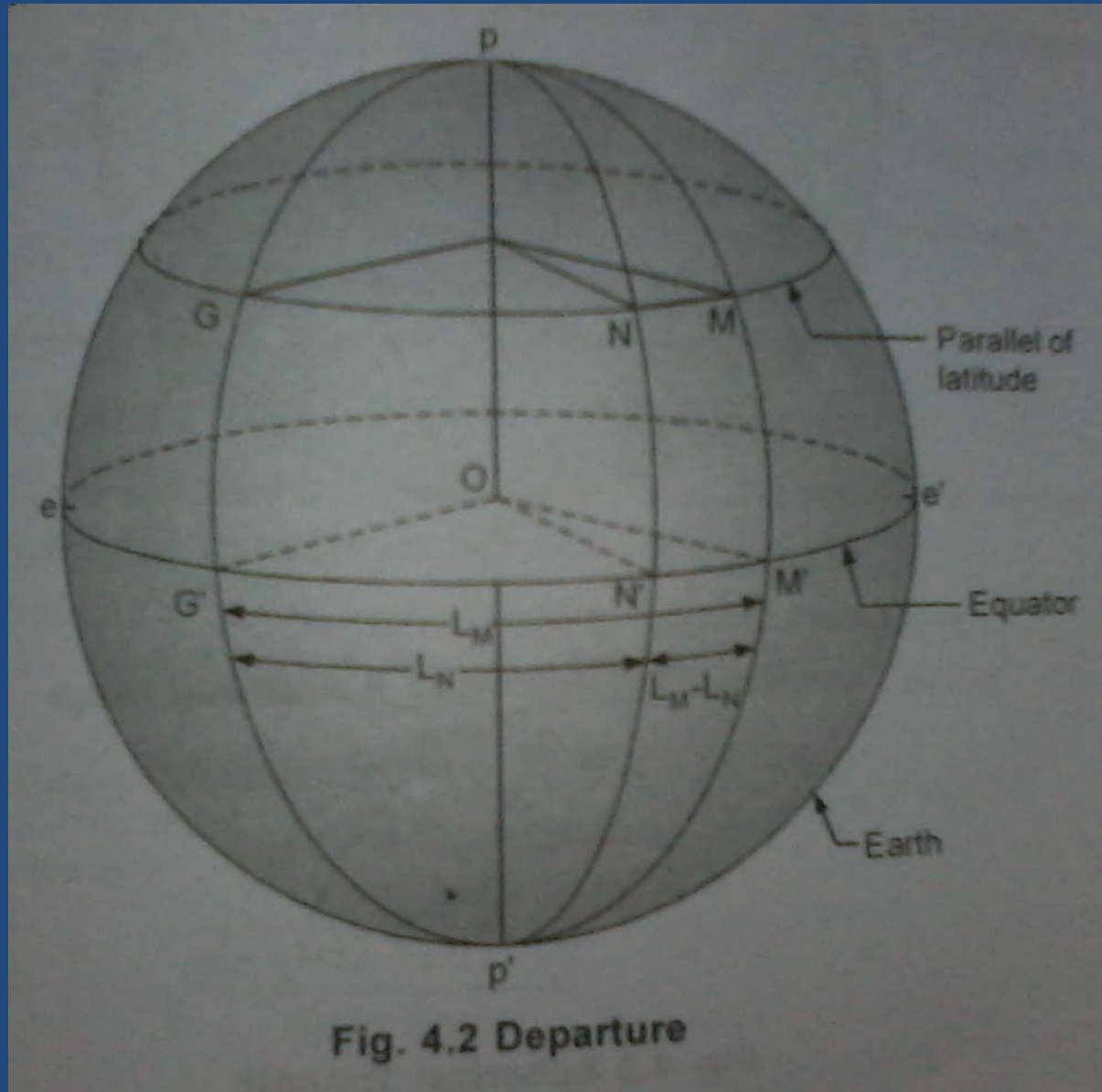


Fig. 4.2 Departure

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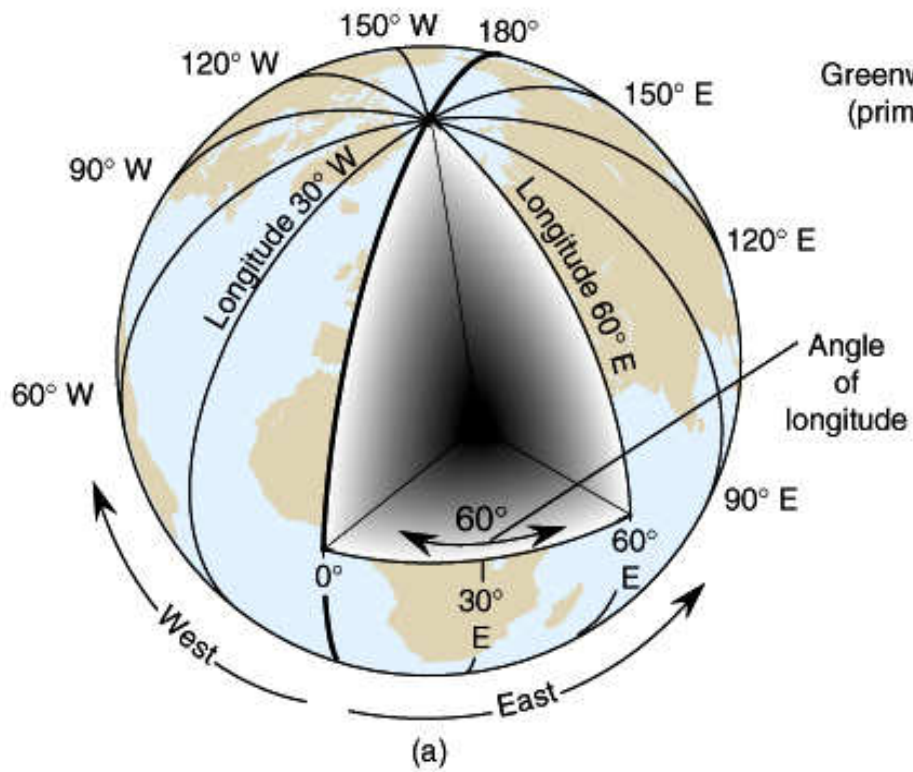
Longitude = Angle G'OM' = Arc G'M'

DEFINITION OF ASTRONOMICAL TERMS

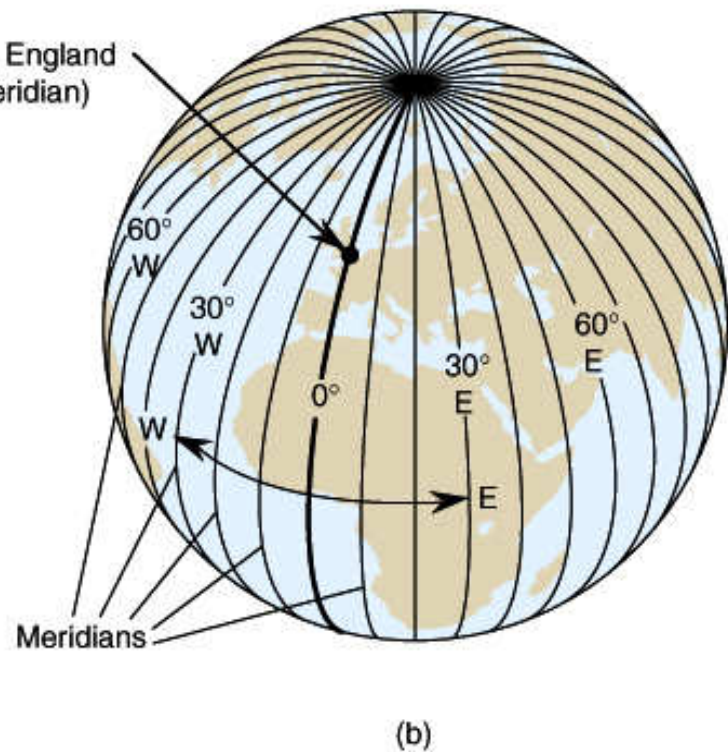
(13) The Longitude (ϕ): (Rekahn's)

- The longitude of the place is the angle between a fixed reference meridian called the **prime** or **first meridian** and the meridian of the place.
- The Prime meridian universally adopted is that of Greenwich.
- The longitude of any place varies between 0° to 180°
- It is reckoned as ϕ° East or West of Greenwich.

Longitude



Greenwich, England
(prime meridian)



DEFINITION OF ASTRONOMICAL TERMS

(14) The Altitude (α):

- The altitude ' α ' of celestial or heavenly body (The Sun, The Moon, The Star,)
- The angular distance above Horizon as measured on the Vertical circle passing through the body is called as altitude (' α ')

DEFINITION OF ASTRONOMICAL TERMS

(15) The Co-altitude or zenith distance (z):

- It is the angular distance of heavenly body from the zenith.
- It is the compliment of the altitude
i. e $z = (90 - \alpha)$.

DEFINITION OF ASTRONOMICAL TERMS

(16) The Azimuth (A):

- The azimuth of a heavenly body is the angle between the observer's meridian and the vertical circle passing through the heavenly body

DEFINITION OF ASTRONOMICAL TERMS

(17) The Declination (δ):

- The declination of a celestial body is angular distance from the ~~plane of the equator~~, measured along the star's meridian generally called the declination circle. (i.e great circle passing through the heavenly body and the celestial pole)
- Declination varies from 0 to 90, and is marked + or – according as the body is north or south of the equator.

DEFINITION OF ASTRONOMICAL TERMS

(18)Co-Declination or Polar Distance (p):

✓ It is the angular distance of the heavenly body from the nearer pole.

It is the compliment of the declination i.e., $p = 90 - \delta$

DEFINITION OF ASTRONOMICAL TERMS

(19) Hour circle

- Hour circle are great circle passing through the North and South celestial poles.
- The declination circle of a heavenly body is thus its hour circle.

DEFINITION OF ASTRONOMICAL TERMS

(20) The Hour Angle:

- The Hour Angle of a heavenly body is the angle between the observer's meridian and the declination circle passing through the body.
- The Hour angle is always measured ***westward***

DEFINITION OF ASTRONOMICAL TERMS

(21) **The Right Ascension (R.A.):**

- It is the equatorial angular distance measured *eastward* from the first point of Aries to the hour circle through the heavenly body.

DEFINITION OF ASTRONOMICAL TERMS

(22) The Equinoctial Points:

- The points of the intersection of the ecliptic with the equator are called the equinoctial points.
- The declination of the sun is zero at the equinoctial points.
- The Vernal Equinox or the first point of Aries is the point in which sun's declination changes from ***South to North***, and marks commencement of spring.
- It is a fixed point on celestial sphere.
- The Autumnal Equinox or the first point of Libra is the point in which Sun's declination changes from ***North to South***, and marks the commencement of autumn.
- Both the Equinoctial points are six month apart in time

DEFINITION OF ASTRONOMICAL TERMS

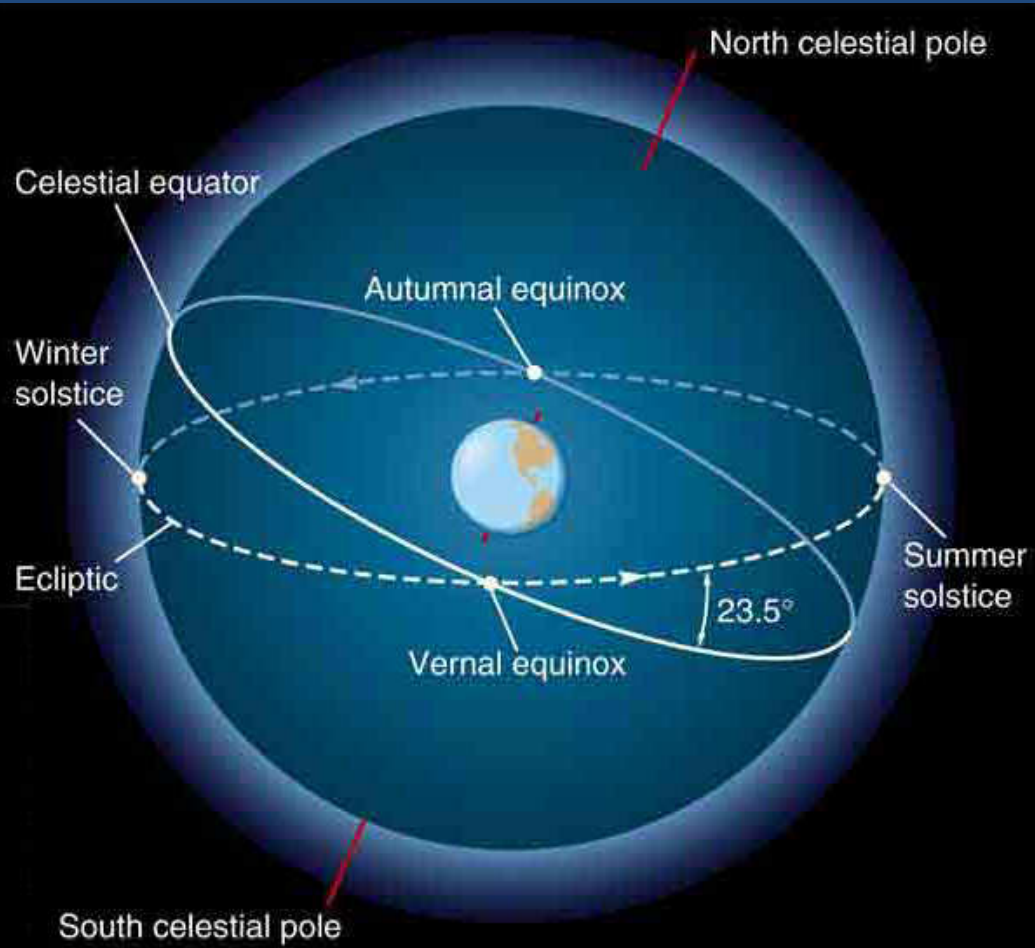
(23) The Ecliptic: (Road of The Sun)

- The Ecliptic is the Great circle of the heavens which the sun appears to describe on the celestial sphere with Earth as a centre in the course of the year.
- The plane of the ecliptic is inclined to the plane of the equator at an angle of about $23^{\circ} 27'$.

DEFINITION OF ASTRONOMICAL TERMS

(24) The Solastices:

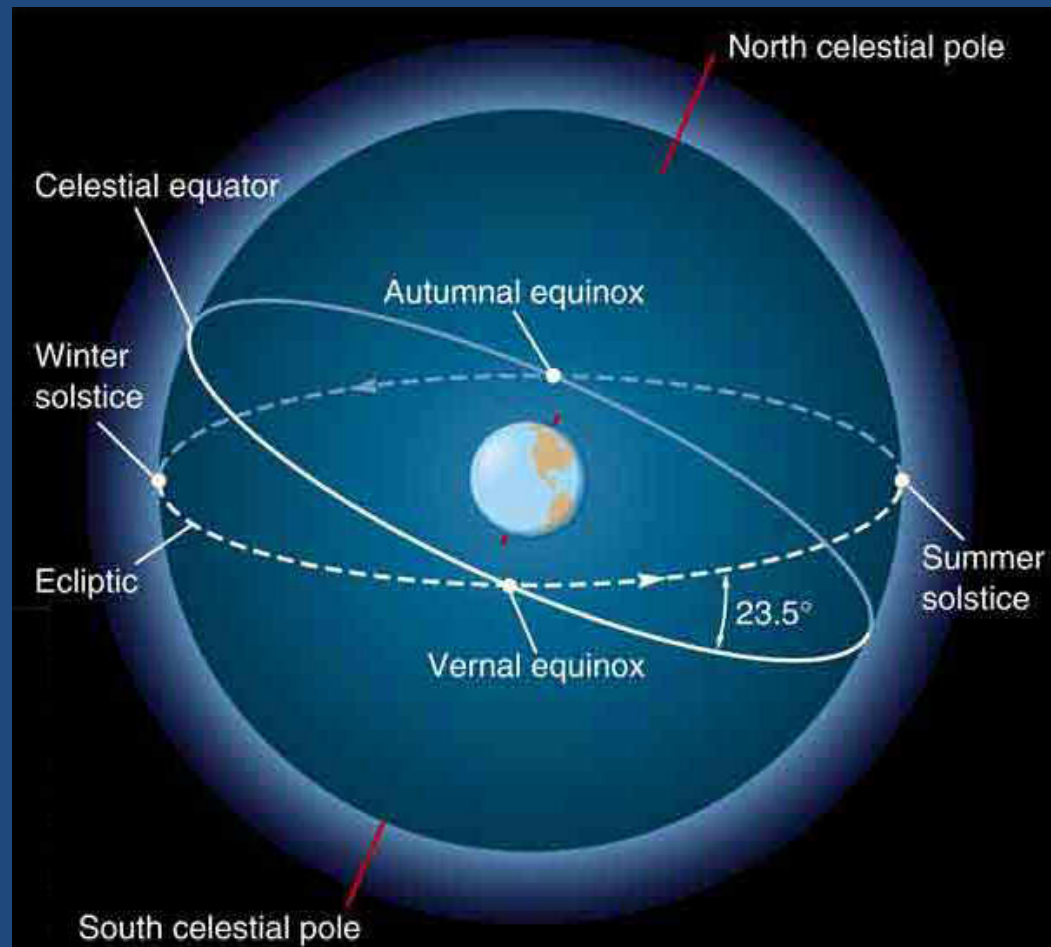
- Solastices are the points at which the North and South declination of the Sun is maximum.
- The point C at which **North** declination of the Sun is maximum is called **Summer solastice**
- The point C' at which **South** declination of the Sun is maximum is known as **winter solastice**.



Event	Date*	Season
Vernal equinox	March 21	Spring begins
Summer solstice	June 22	Summer begins
Autumnal equinox	September 22	Autumn begins
Winter solstice	December 22	Winter begins

* Give or take a day due to leap year and other factors.

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DEFINITION OF ASTRONOMICAL TERMS

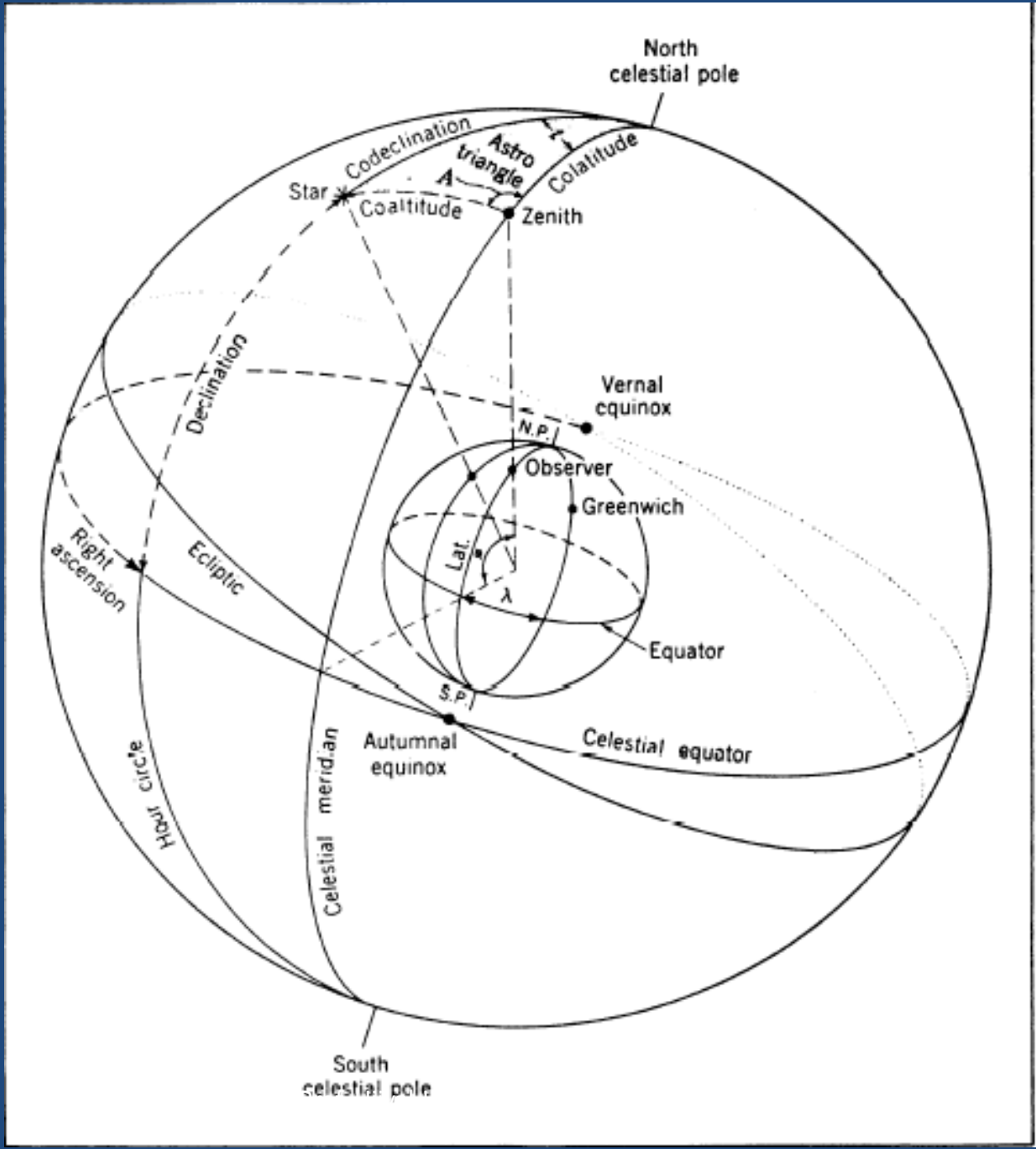
(25) The Celestial Meridian:

- The Great Circle passing through the poles, the zenith and the nadir is called as celestial meridian.
- Celestial Meridian cuts the Horizon and Equator at Right angle.

DEFINITION OF ASTRONOMICAL TERMS

(26) The North, South East and West Directions:

- The North and South points correspond to the projection of the North and South poles on the horizon.



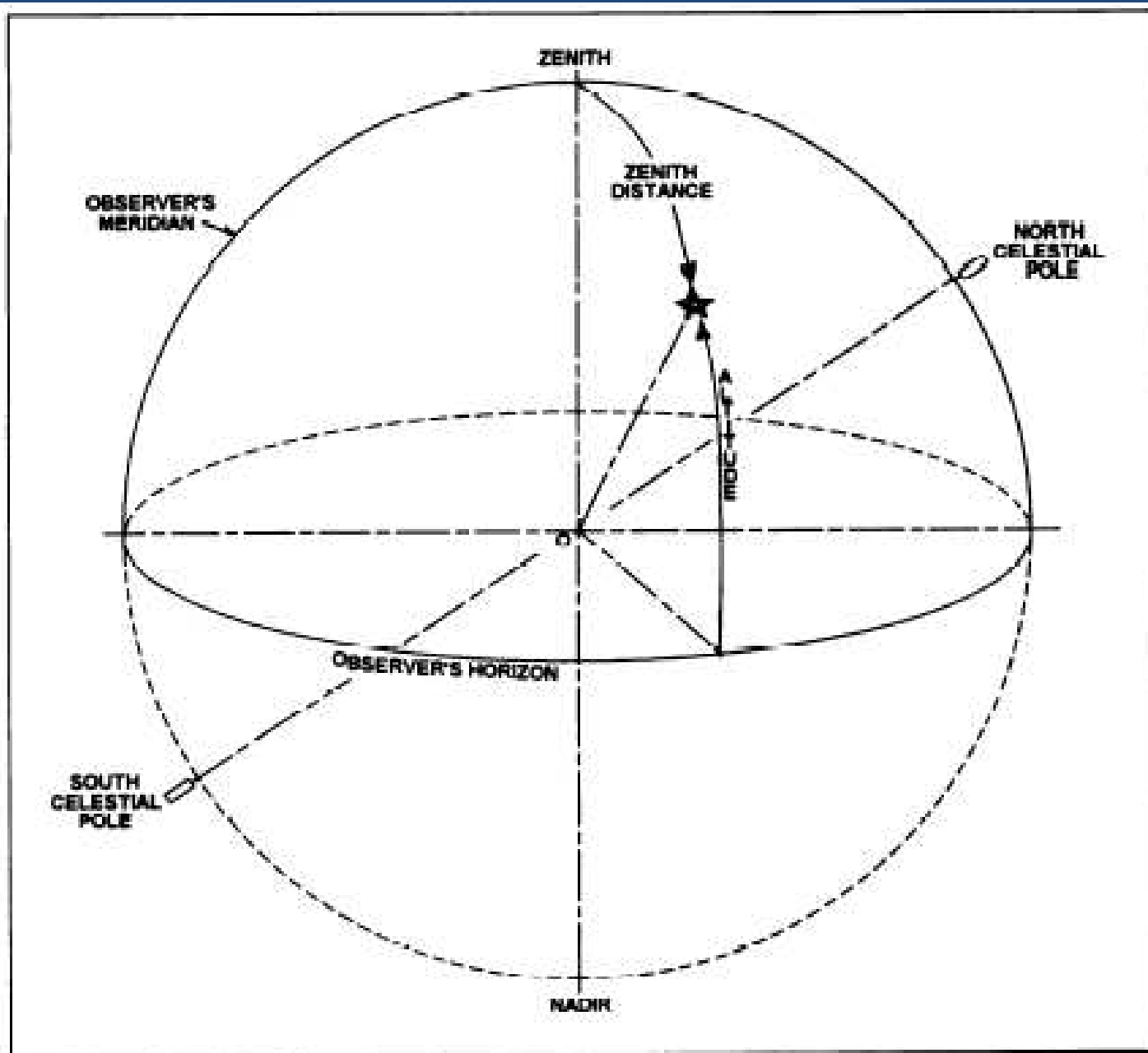
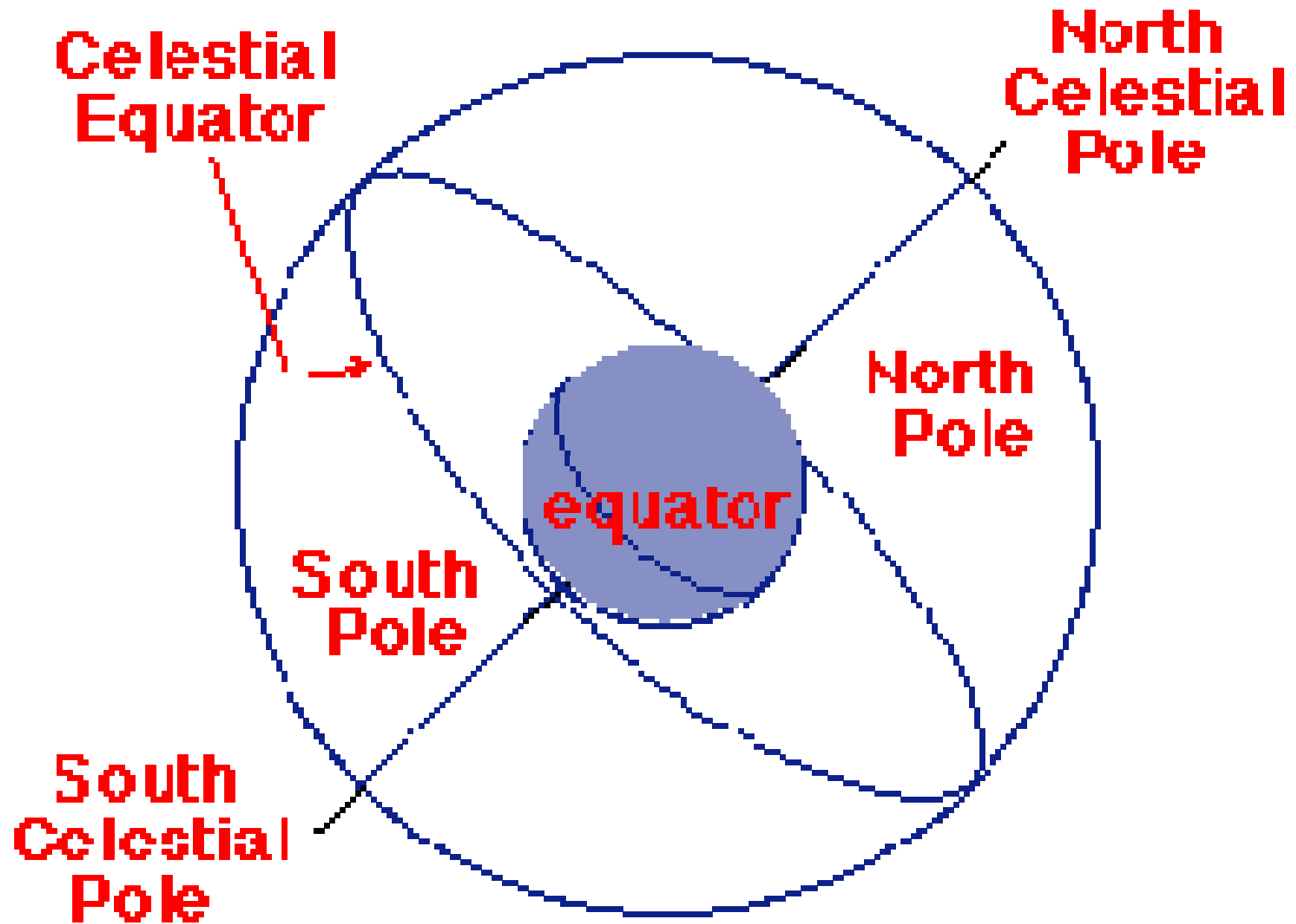
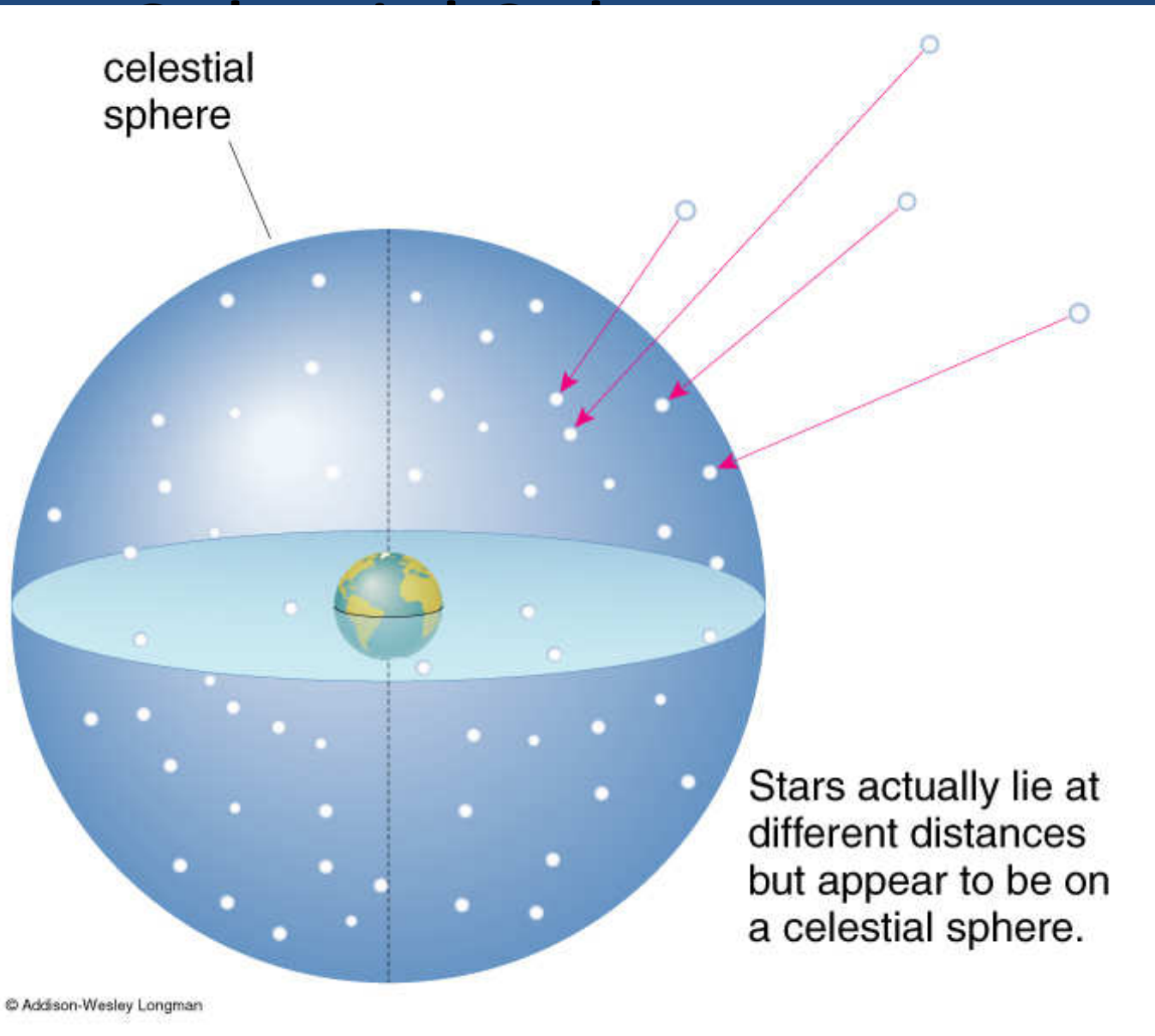
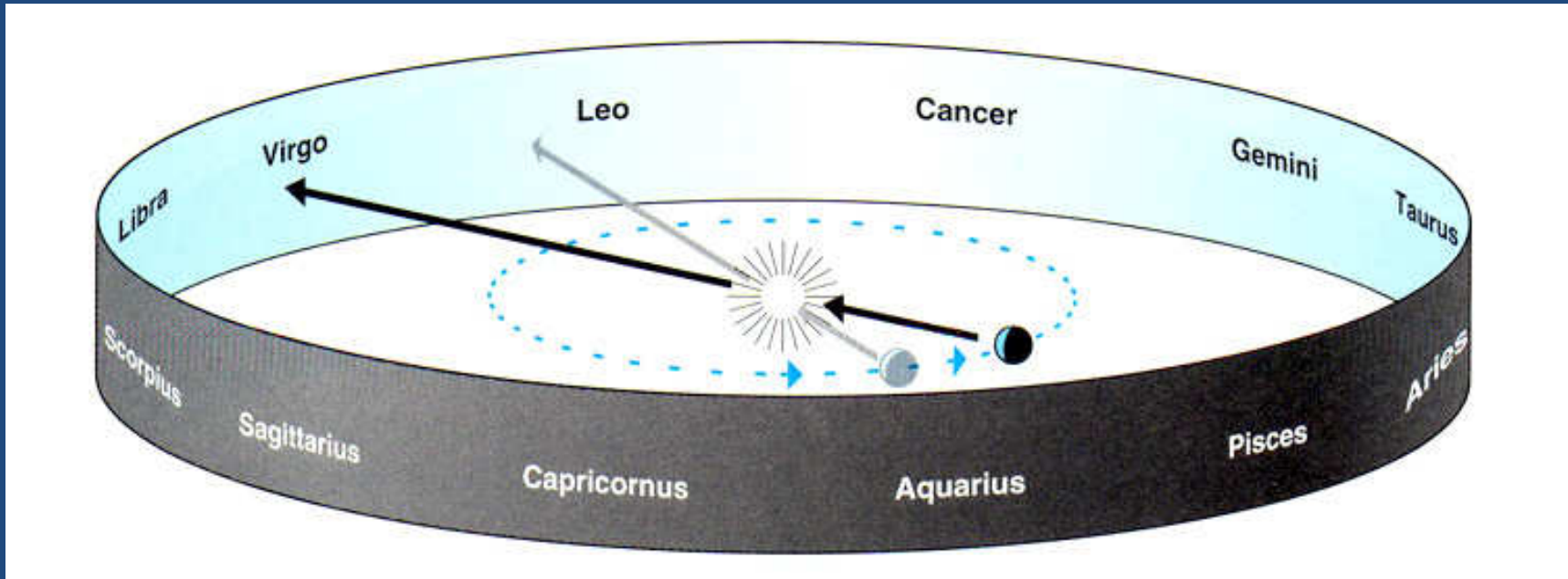


Figure 15-4. Heliocentric system of coordinates.



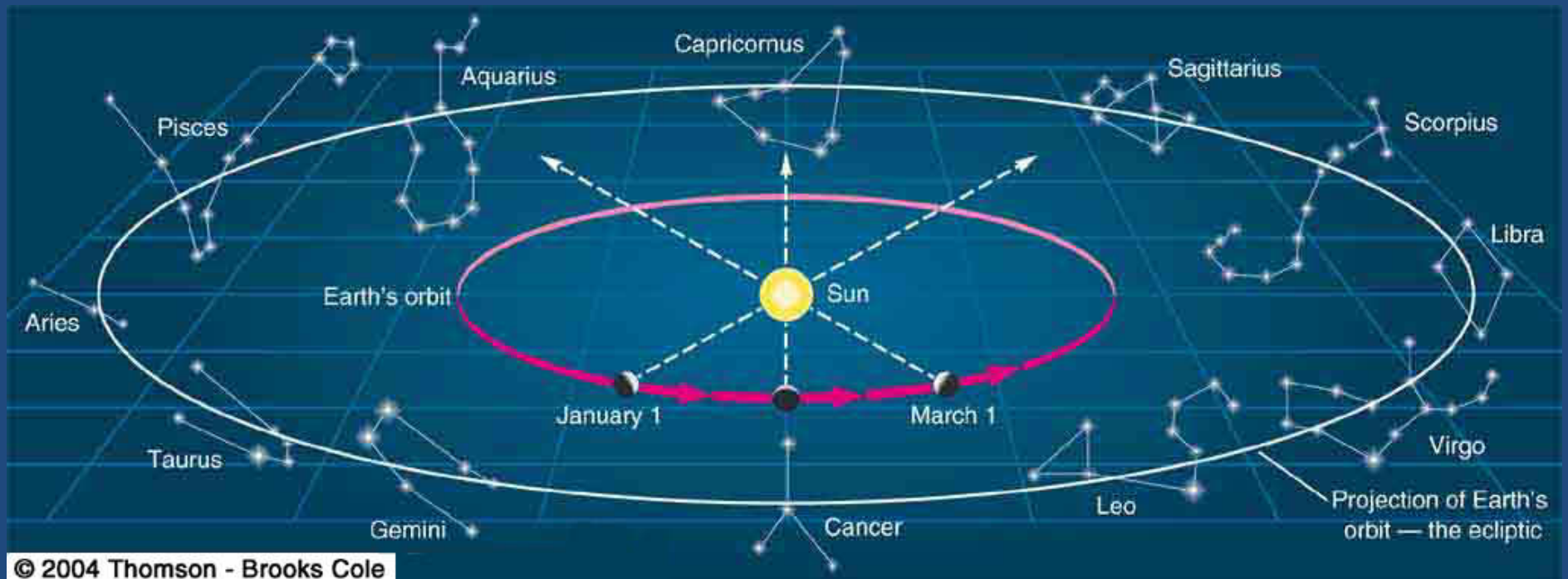




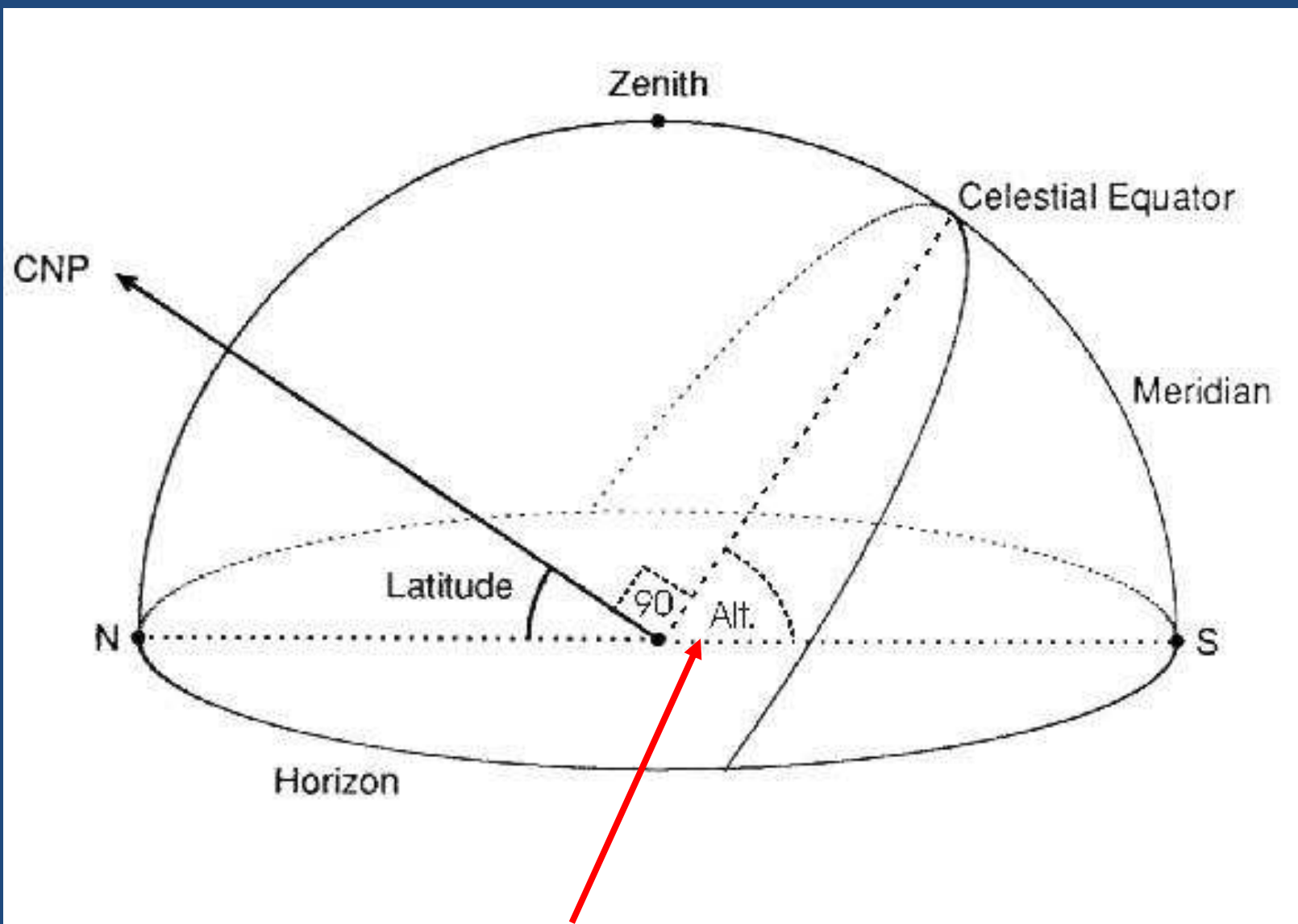
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Ecliptic and Zodiac



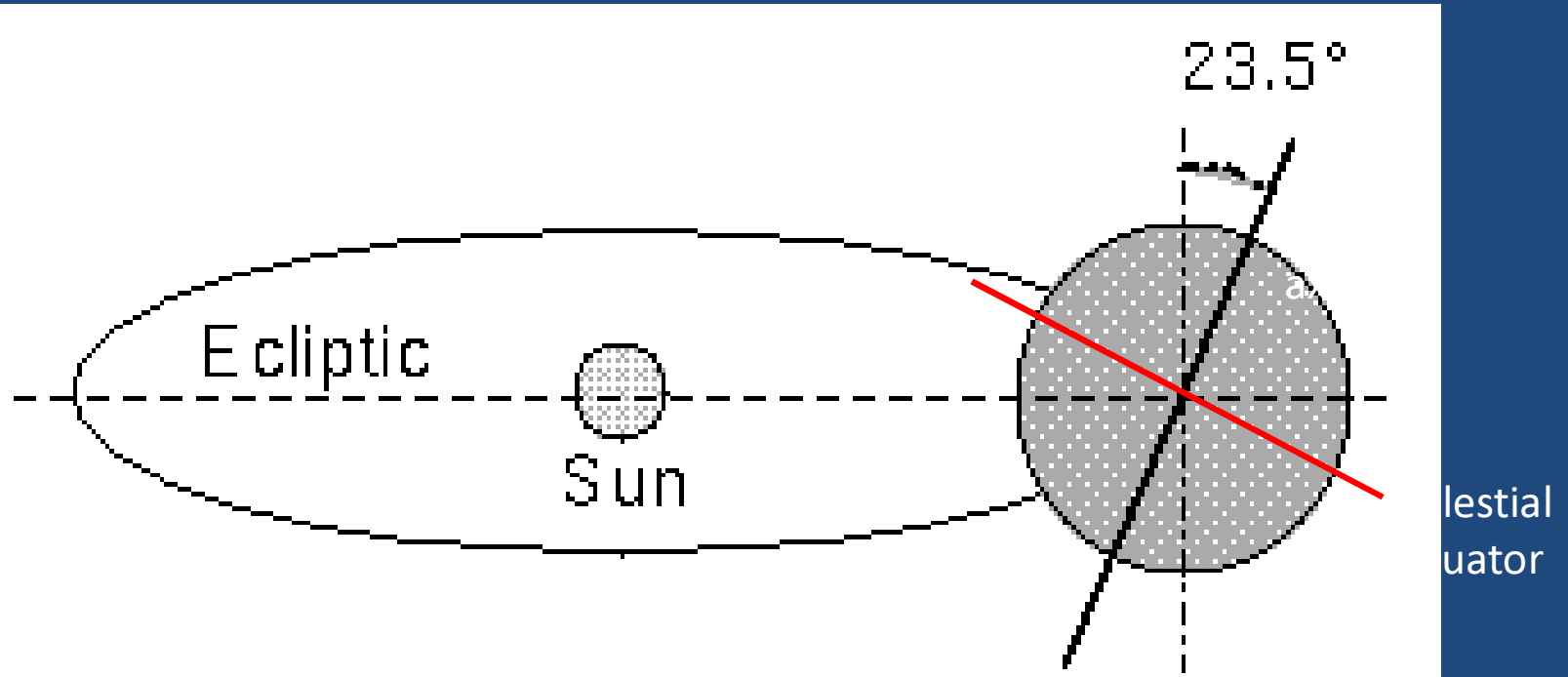
Sun travels $360^\circ/365.25$ days $\sim 1^\circ/\text{day}$



This angle = $90^\circ - \text{Latitude}$!

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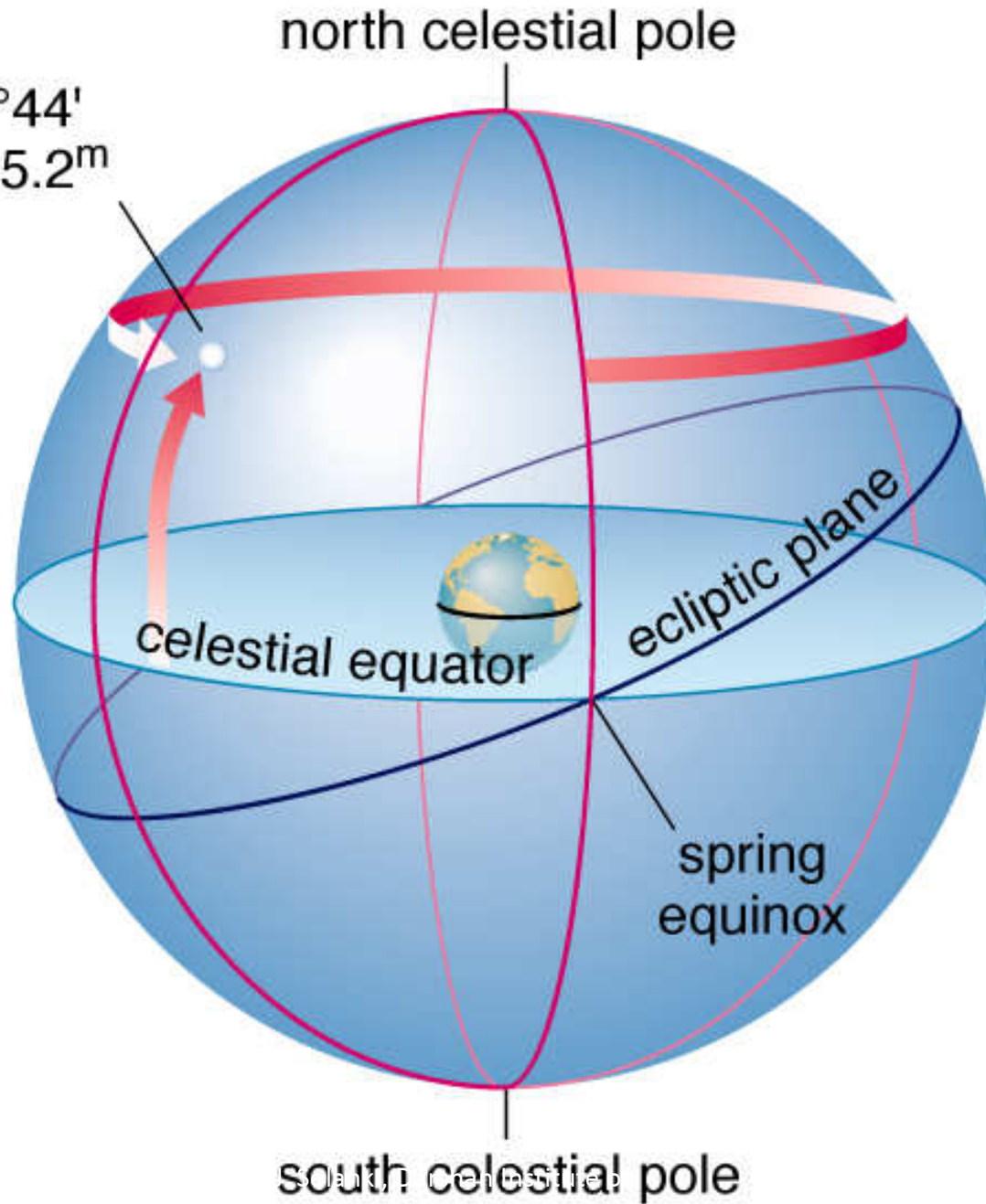
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Earth's rotation axis is tilted by 23.5° with respect to the ecliptic (its orbital plane).

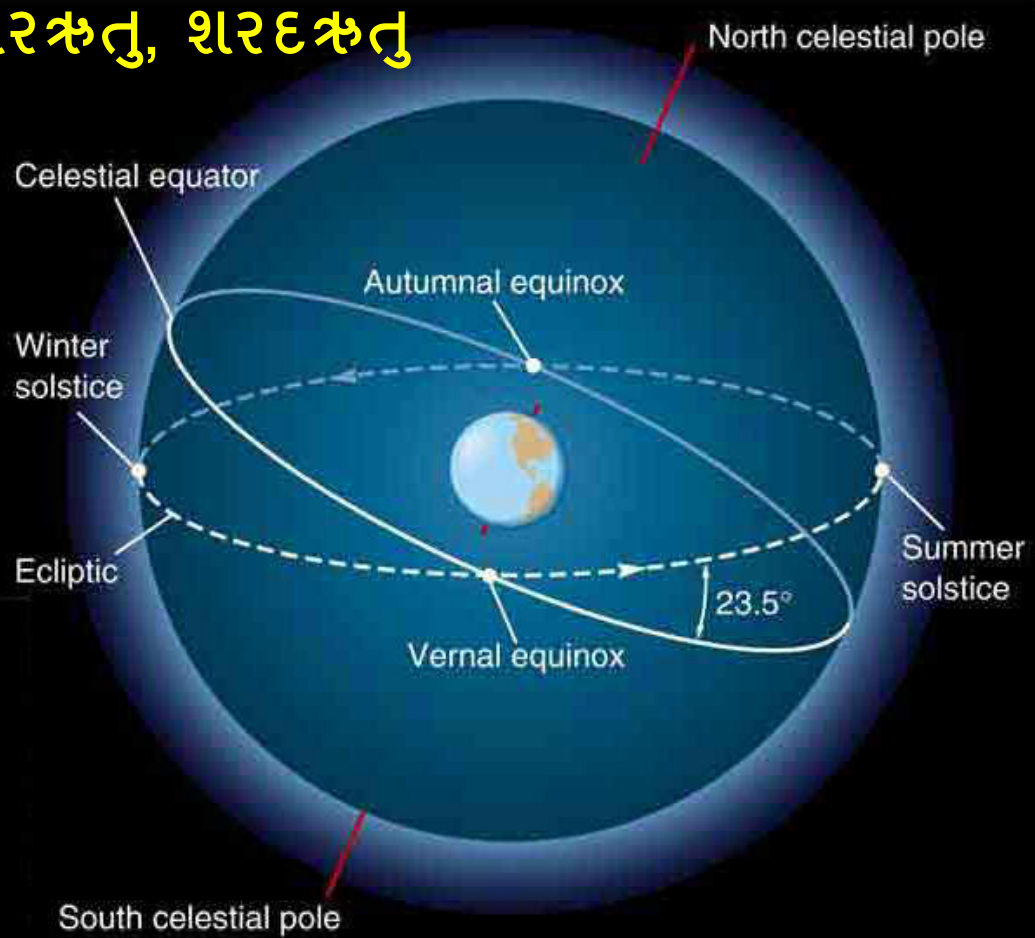
As a result, planes of the ecliptic and celestial equator make an angle 23.5°

Vega
dec = $+38^{\circ}44'$
RA = $18^{\text{h}}35.2^{\text{m}}$



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Autumn = પાલખરઋતુ, શરદઋતુ



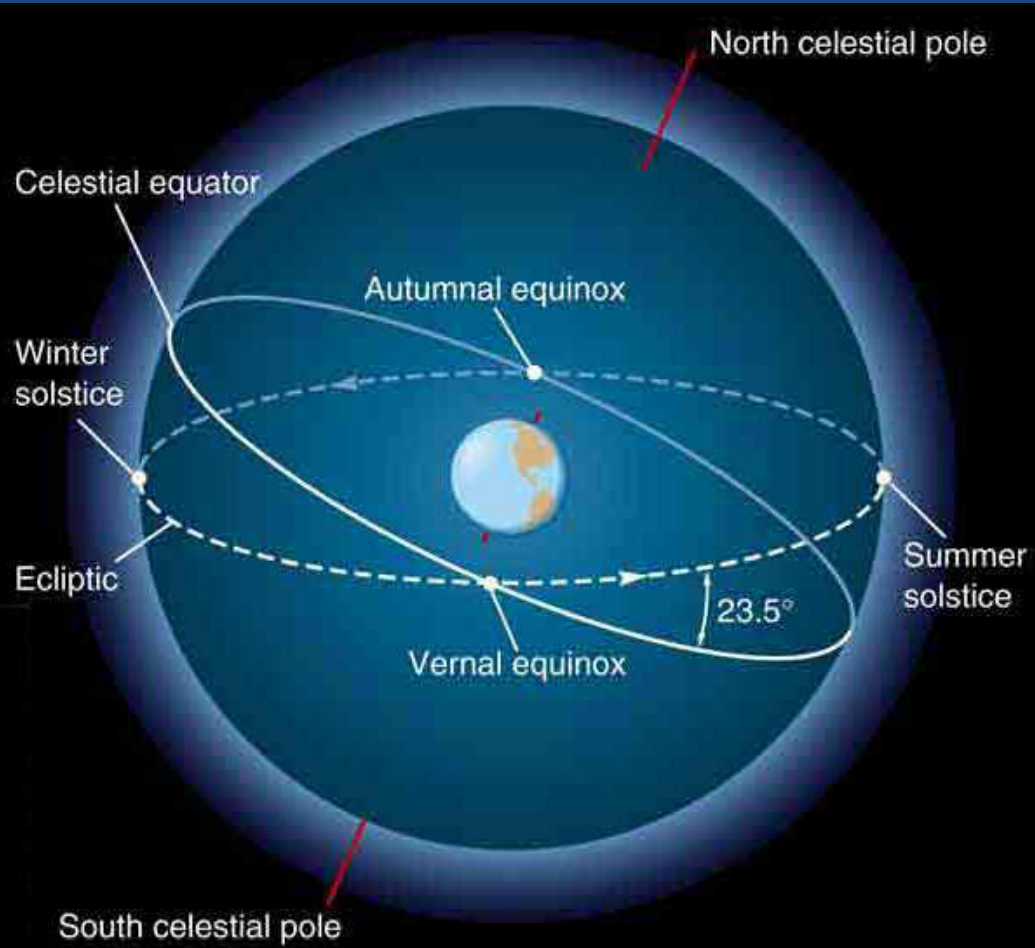
Event	Date*	Season
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* Give or take a day due to leap year and other factors.

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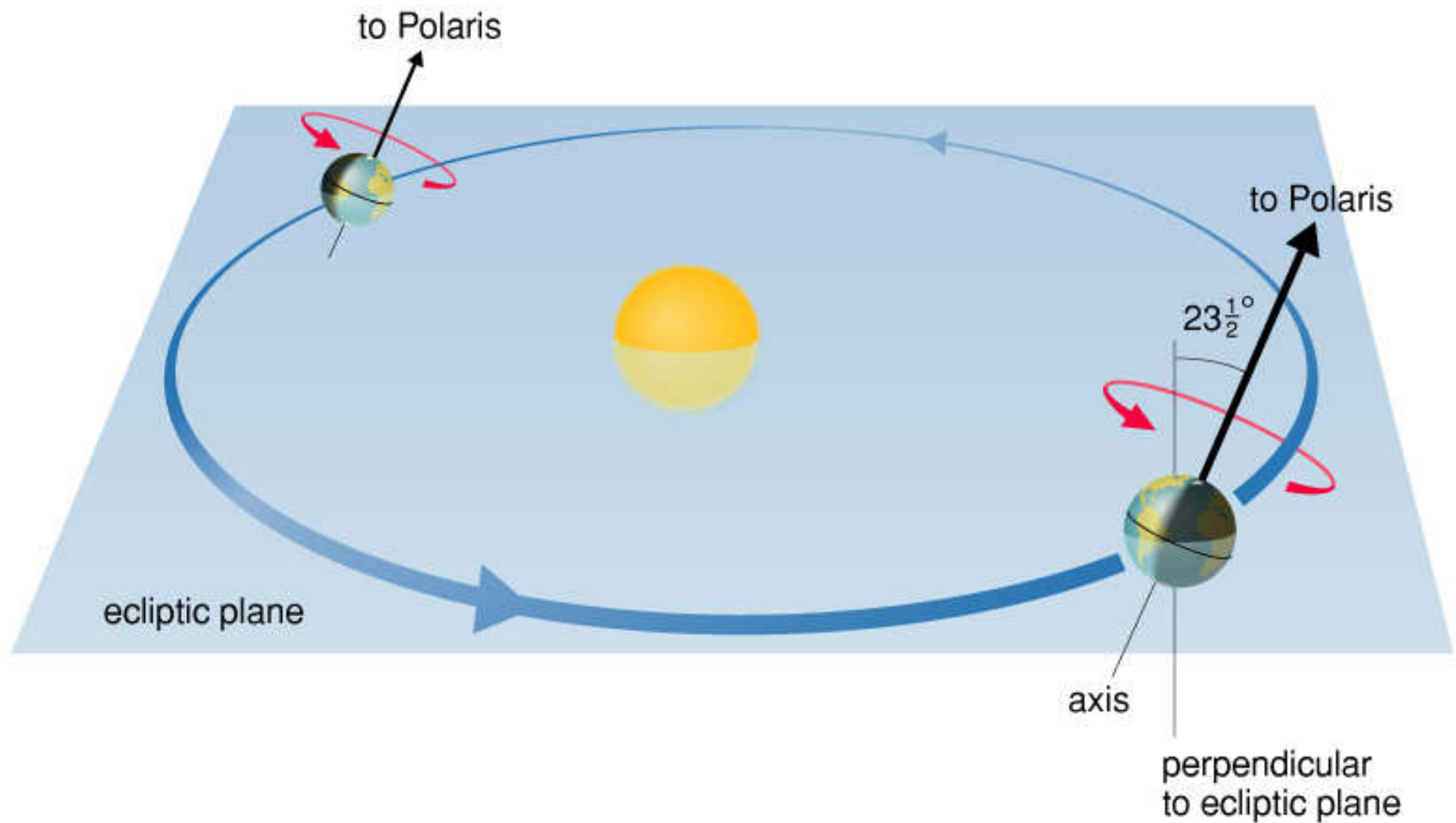
Vernal = વસંતઋતુ



Event	Date*	Season
Vernal equinox	March 21	Spring begins
Summer solstice	June 22	Summer begins
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* Give or take a day due to leap year and other factors.

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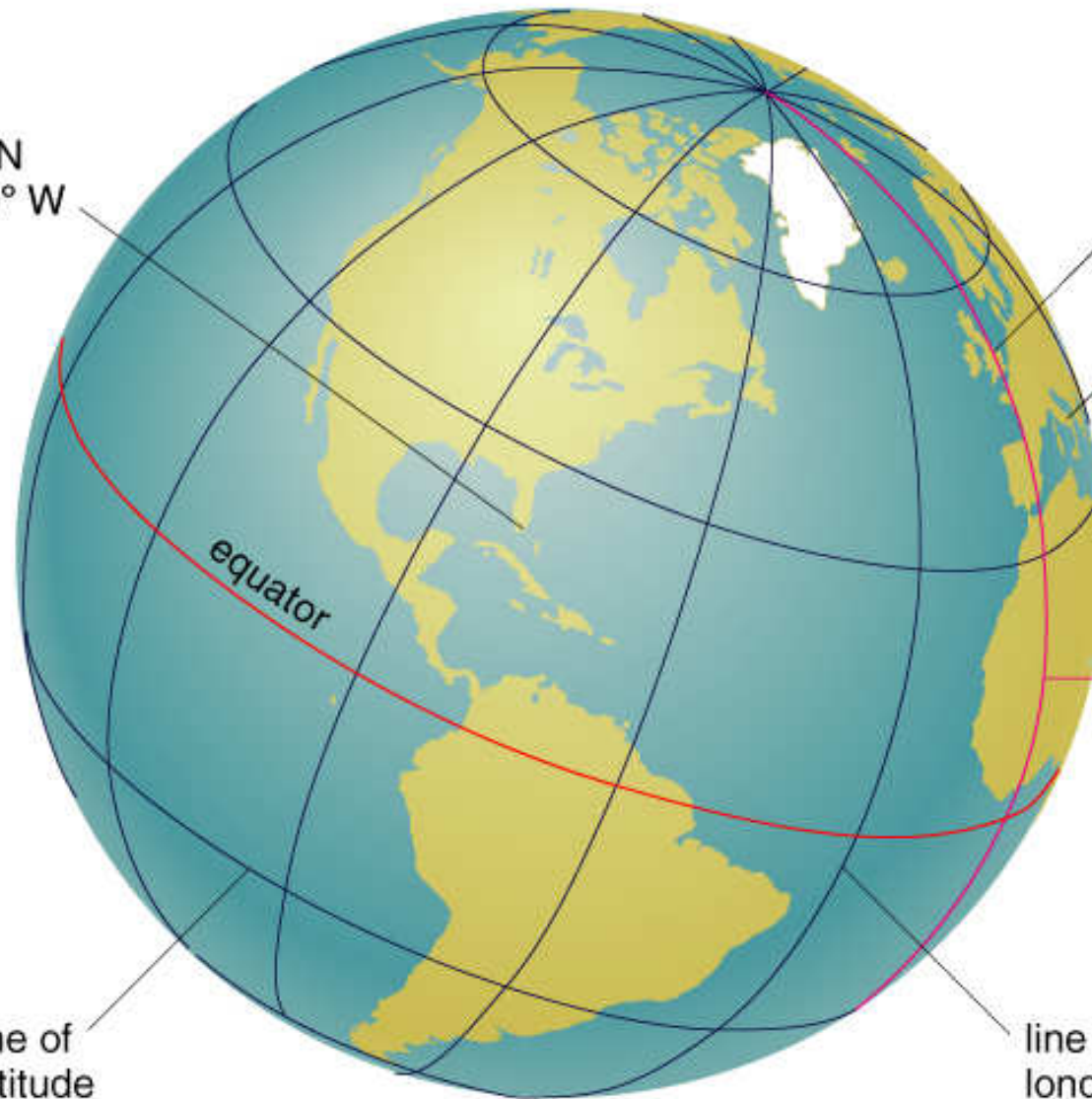


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Miami:
latitude = 26° N
longitude = 80° W

Greenwich

Rome:
latitude = 42° N
longitude = 12° E



line of
latitude

line of
longitude

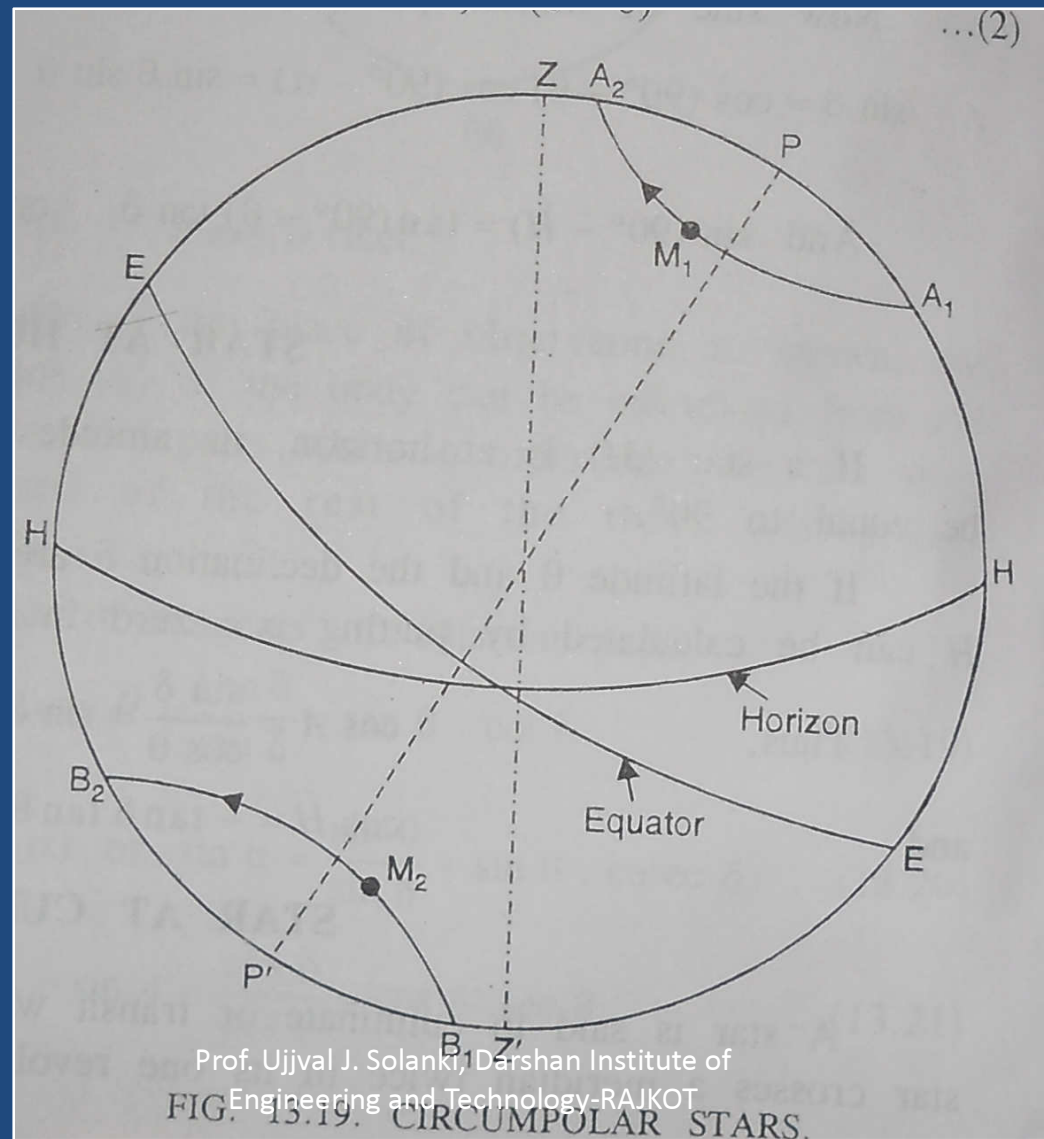
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Methods for determination of Azimuth of survey line

- **Total six methods**

1. Making observation on circumpolar star at transit.
2. By observation on circum polar star at elongation.
3. By making observation on star at equal altitudes.
4. By taking observation on polaris.
5. By taking the ex- meridian altitude of the stars.
6. By hour angle of the star or sun.

1 CIRCUMPOLAR STAR



2 STAR AT CULMINATION

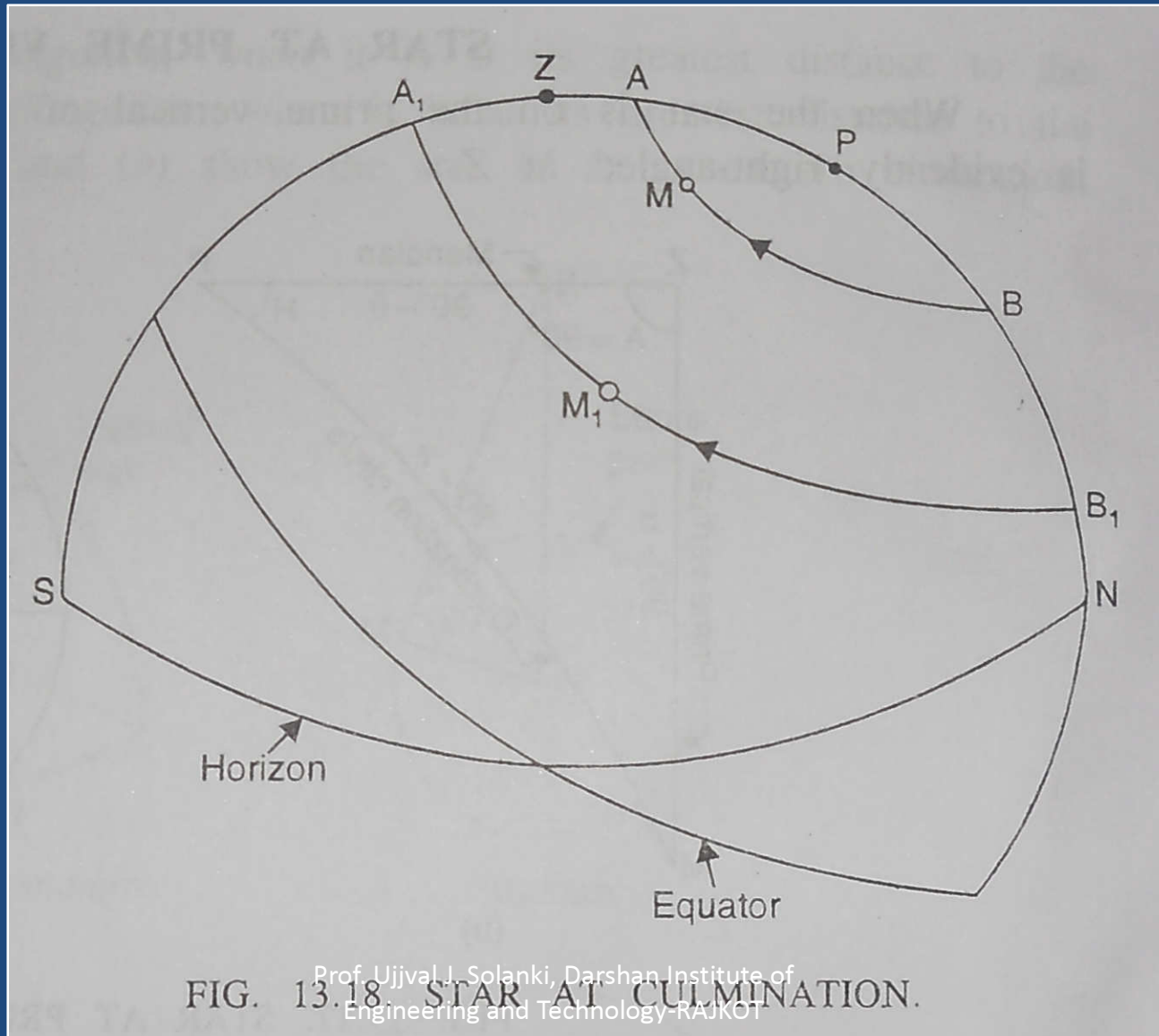
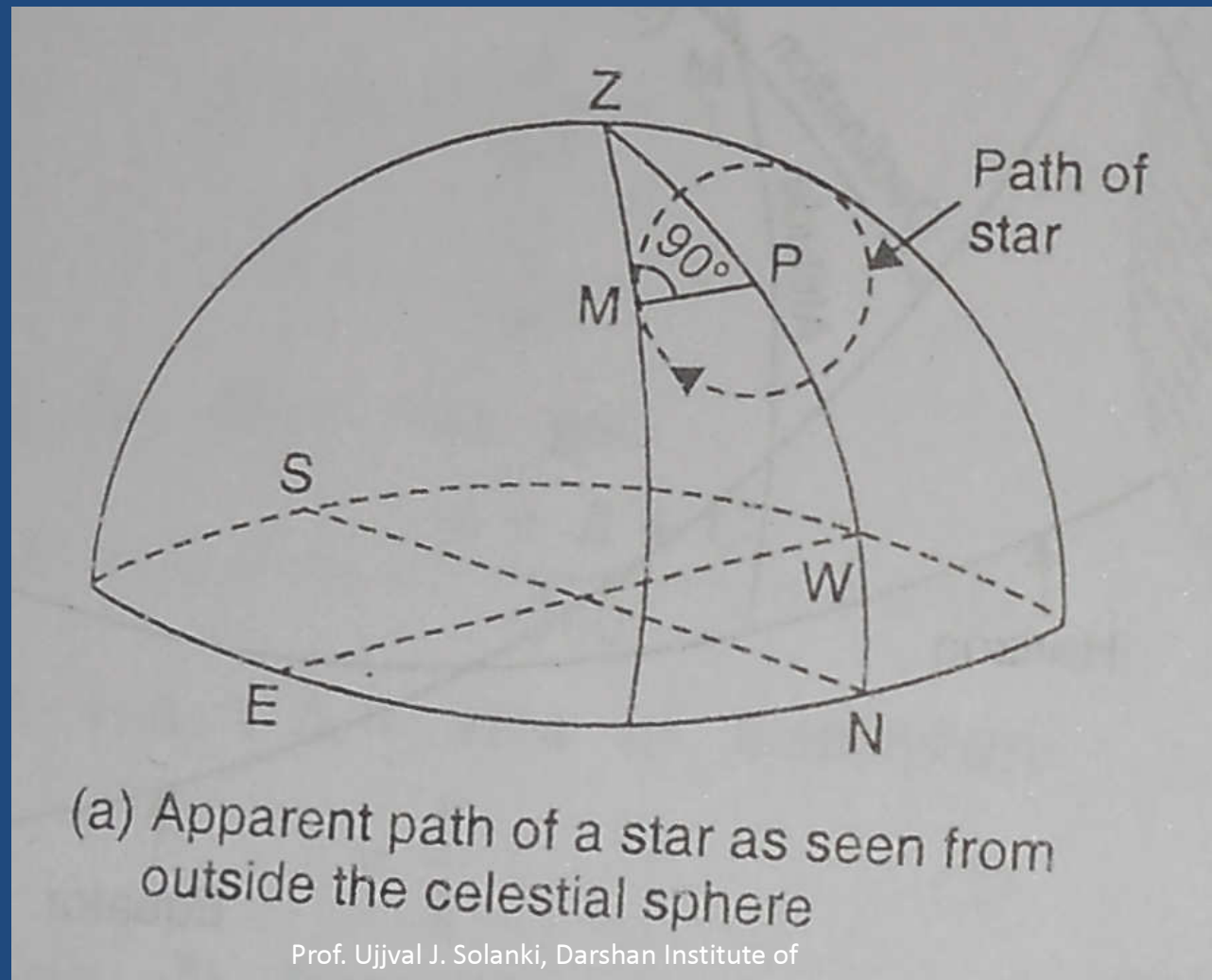


FIG. 13.18. STAR AT CULMINATION.

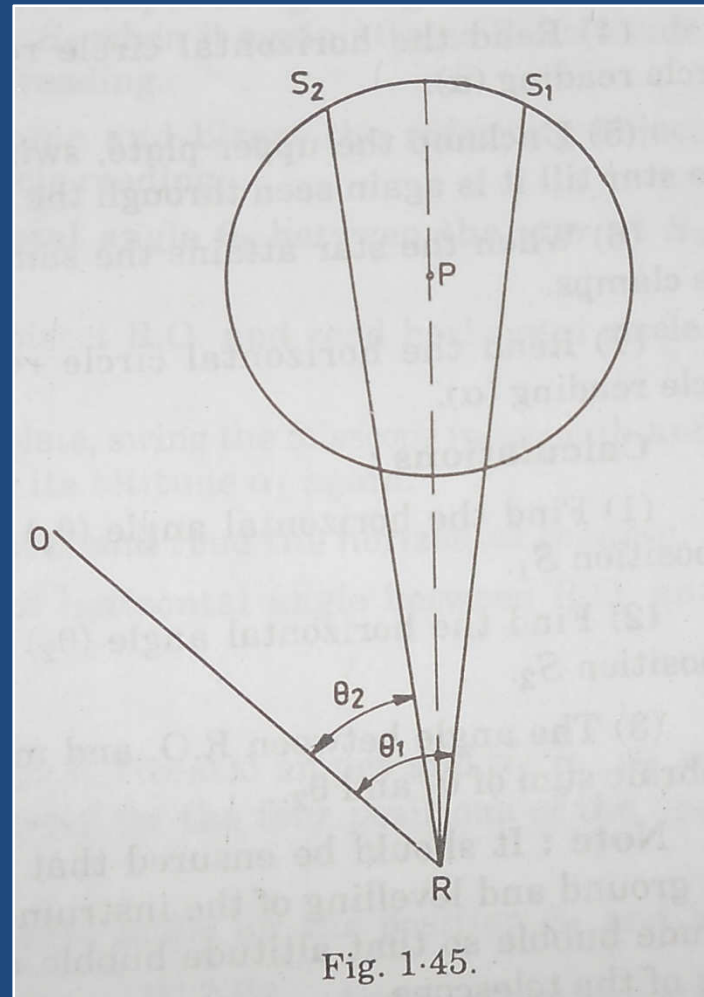
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3 Star at elongation



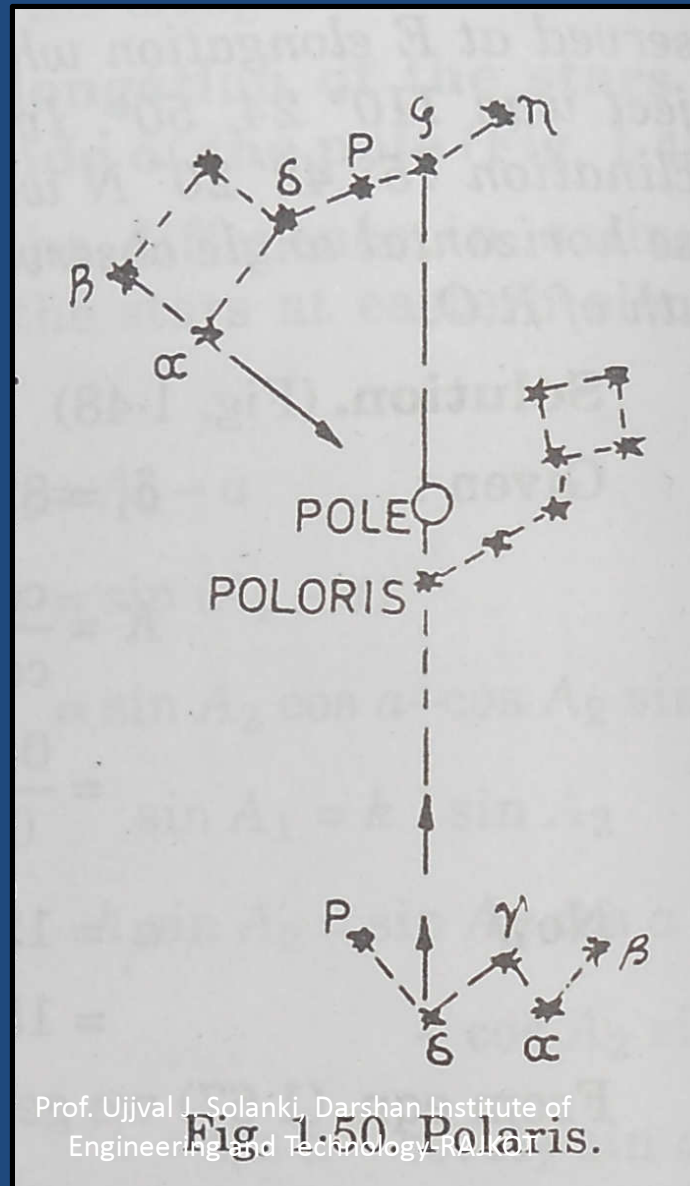
(a) Apparent path of a star as seen from outside the celestial sphere

4 Star at equal altitudes



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By taking observation on Polaris.



CO-ORDINATE SYSTEMS

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Coordinate system- 1) Horizon system

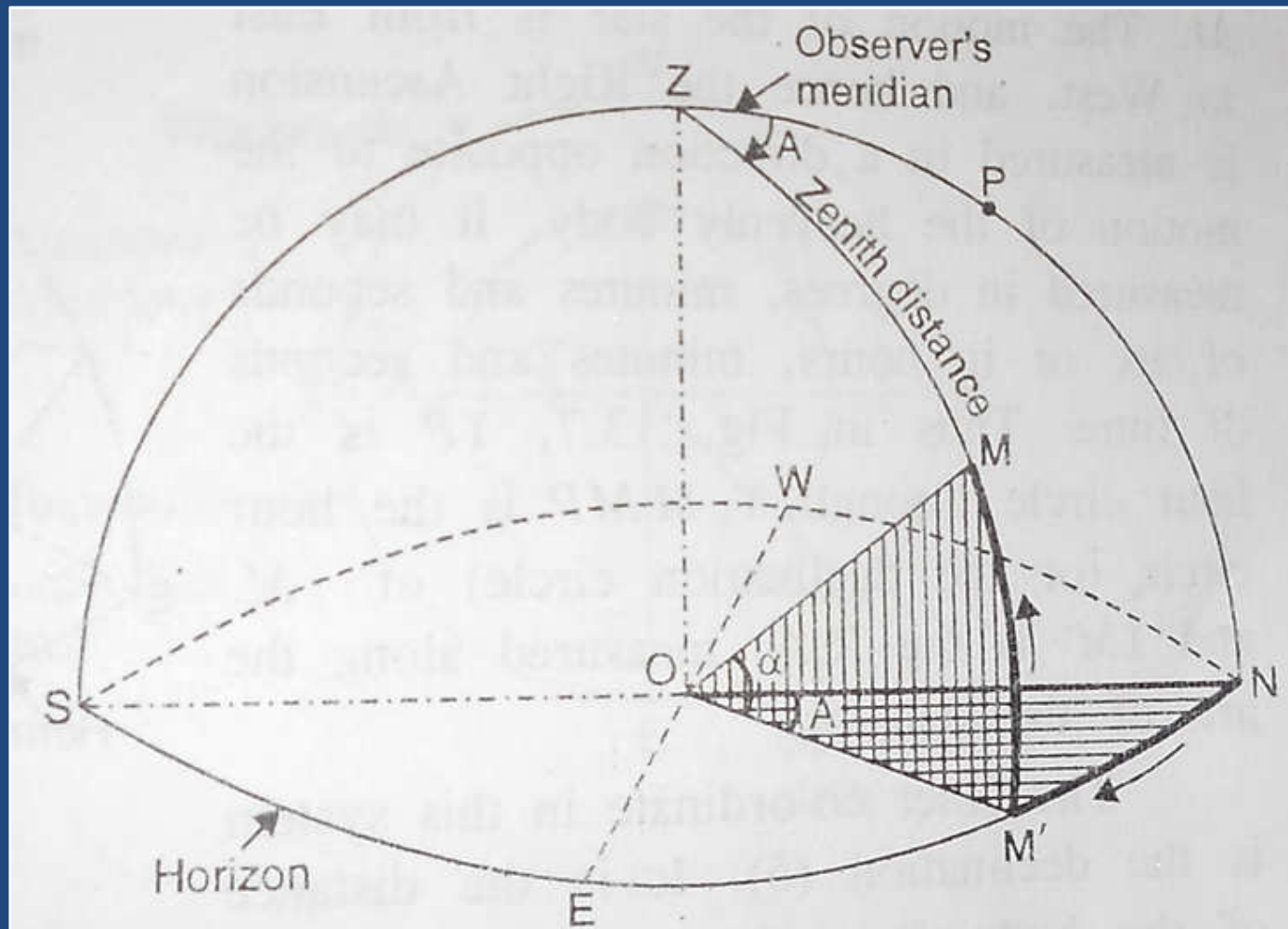
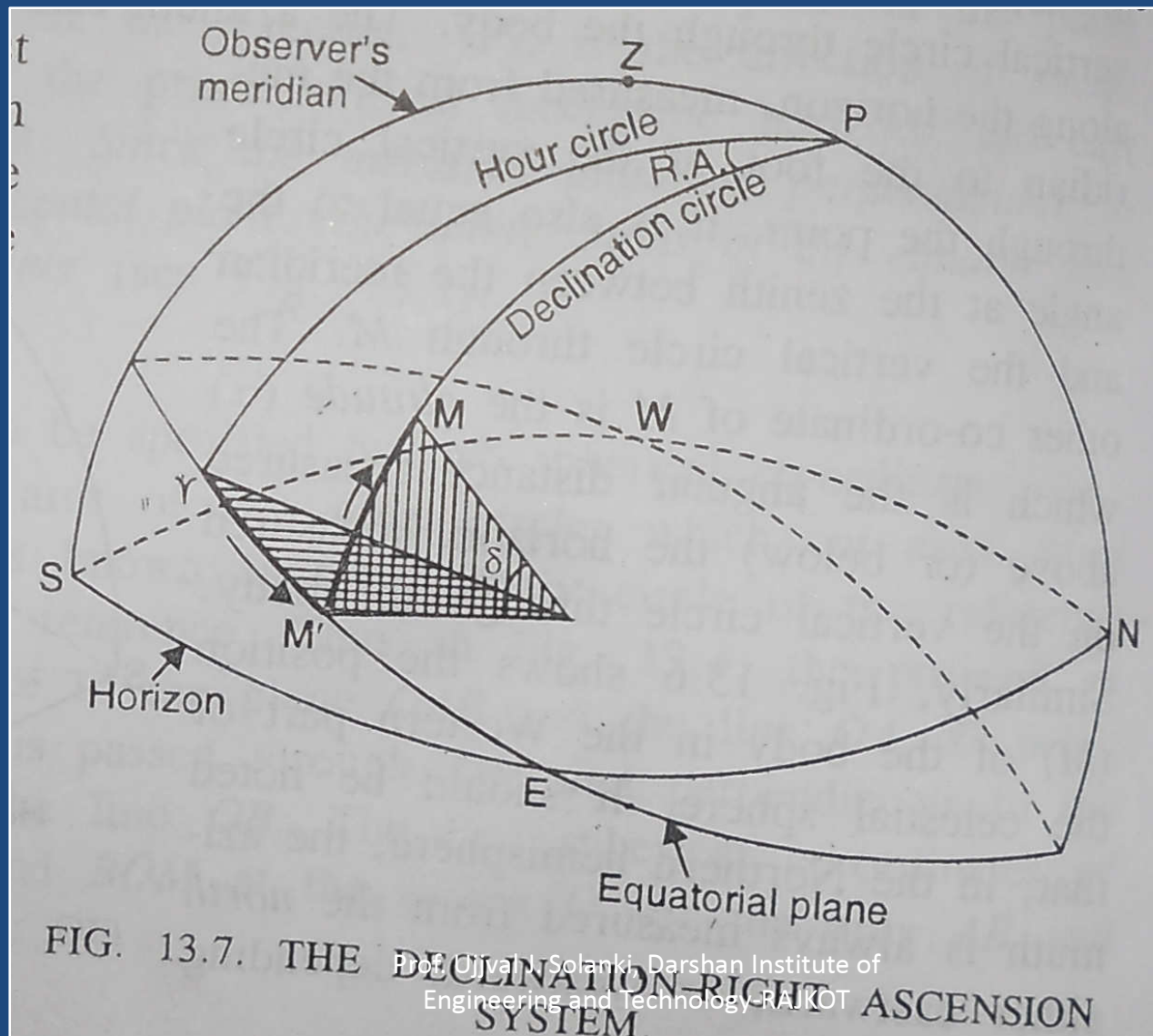


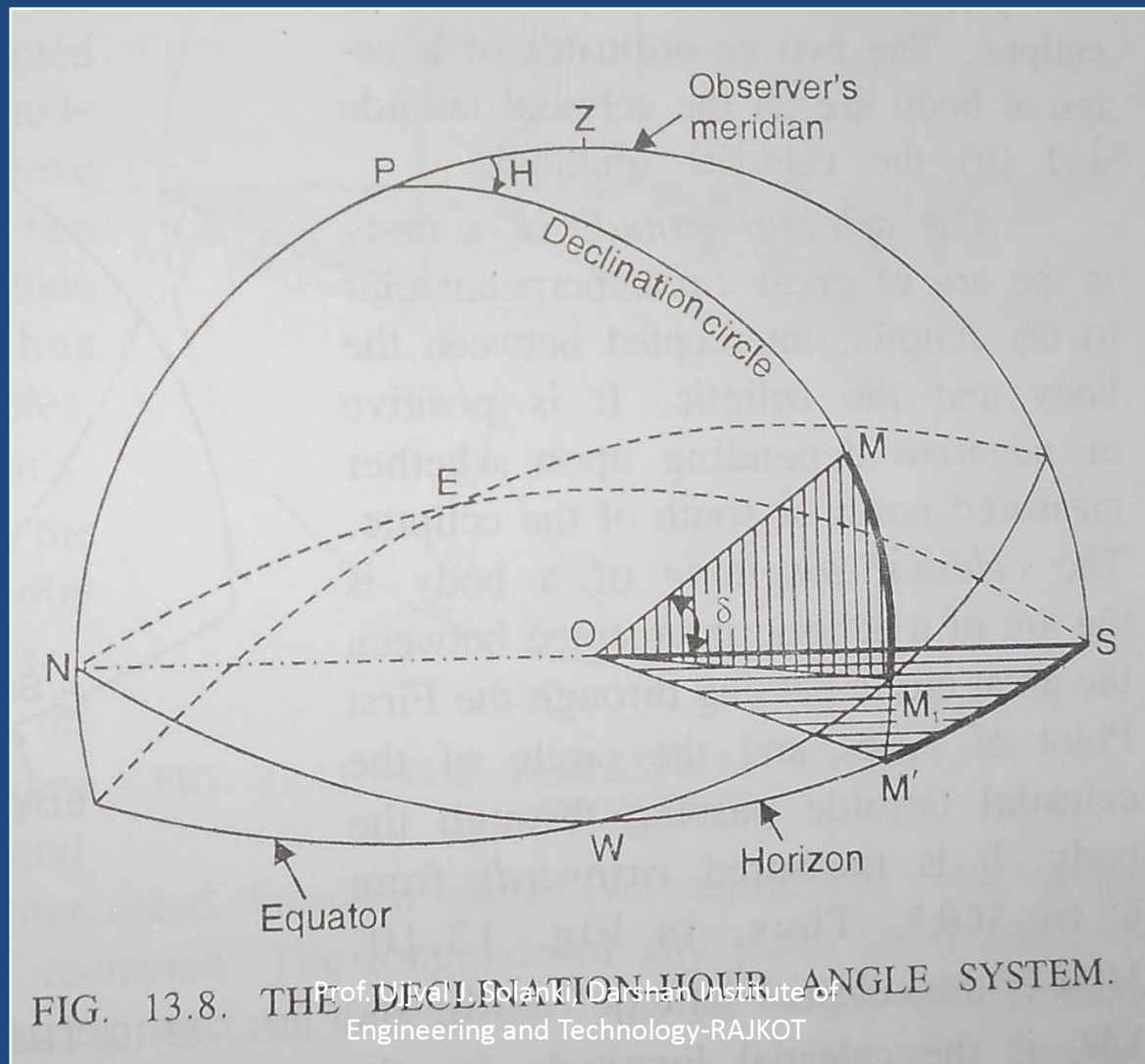
FIG. 13.5 BODY IN THE EASTERN PART OF THE CELESTIAL SPHERE.

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2) Independent equatorial system (The declination and Right ascension system)



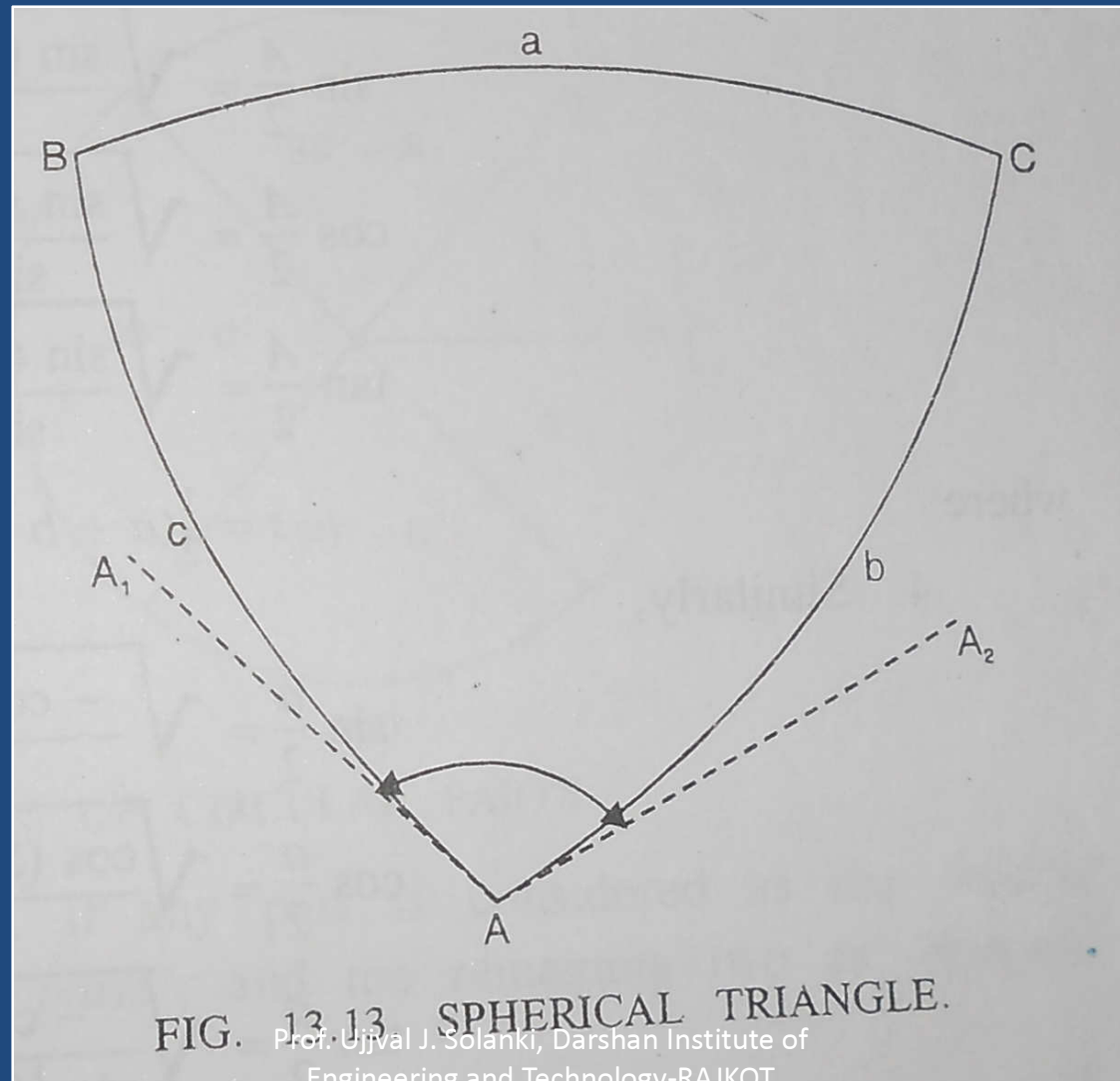
3) The dependent equatorial system (The declination and hour angle system)



Spherical Trigonometry and Spherical Triangle

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Spherical triangle



Properties of spherical triangle

- 1) Any angle is less than two right angles or π .
- 2) The sum of three angles is less than six right angles or 3π .
- 3) The sum of any two sides is greater than the third.
- 4) If the sum of any two sides is equal to two right angles or π , the sum of the angles opposite them is equal to two right angles or π .
- 5) The smaller angle is opposite the smaller side.

Formulae in Spherical Trigonometry

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The nautical mile

- The distance on arc of the great circle corresponding to angle of 1 minute subtended by the arc at the center of the earth.

- One nautical

mile = Circumference of the great circle

$$360^\circ \times 60$$

$$= (2 \times \pi \times 6370) / 360 \times 60$$

- = 1.852 Km.

Example